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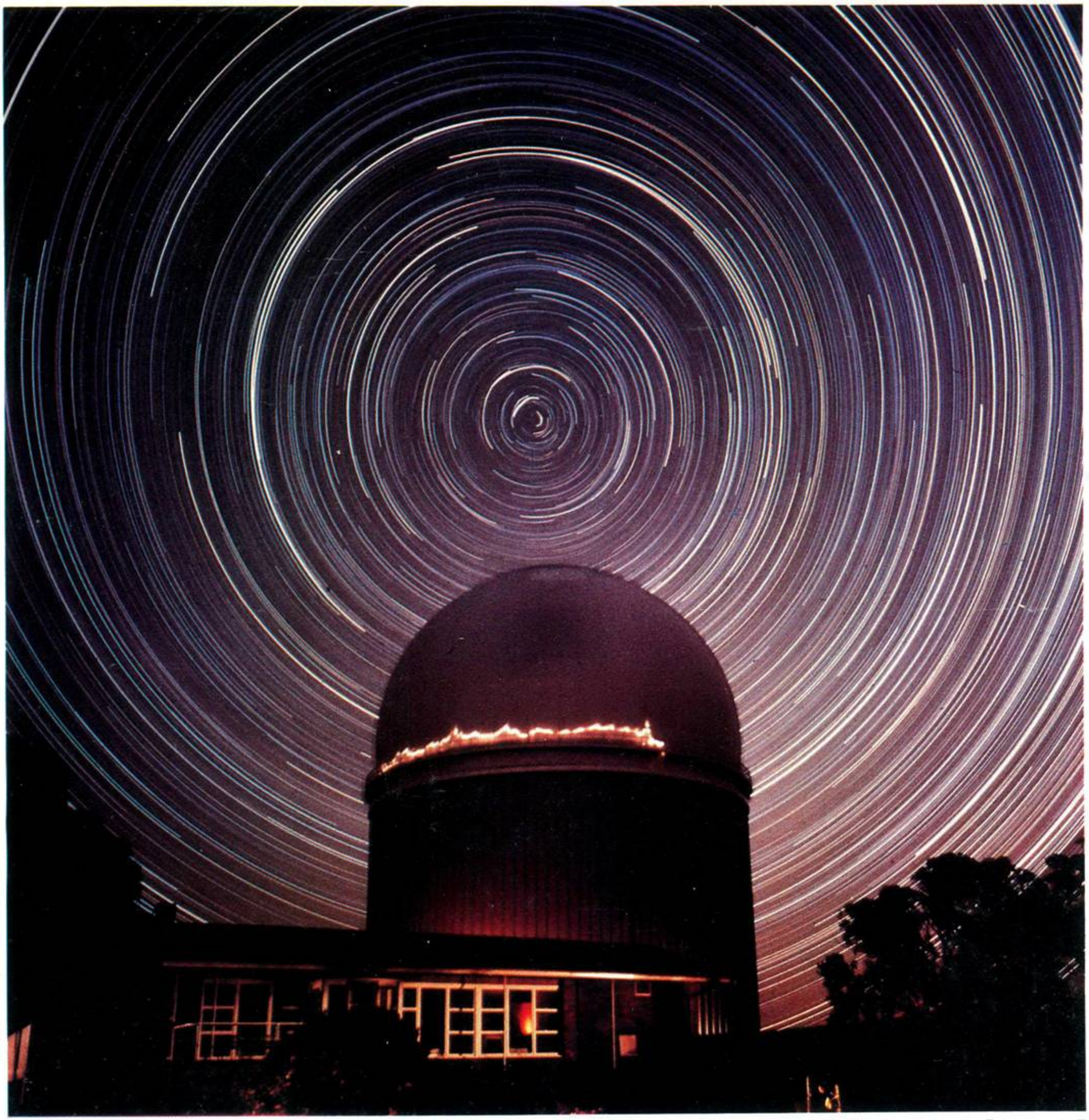

Southern Skies Explored

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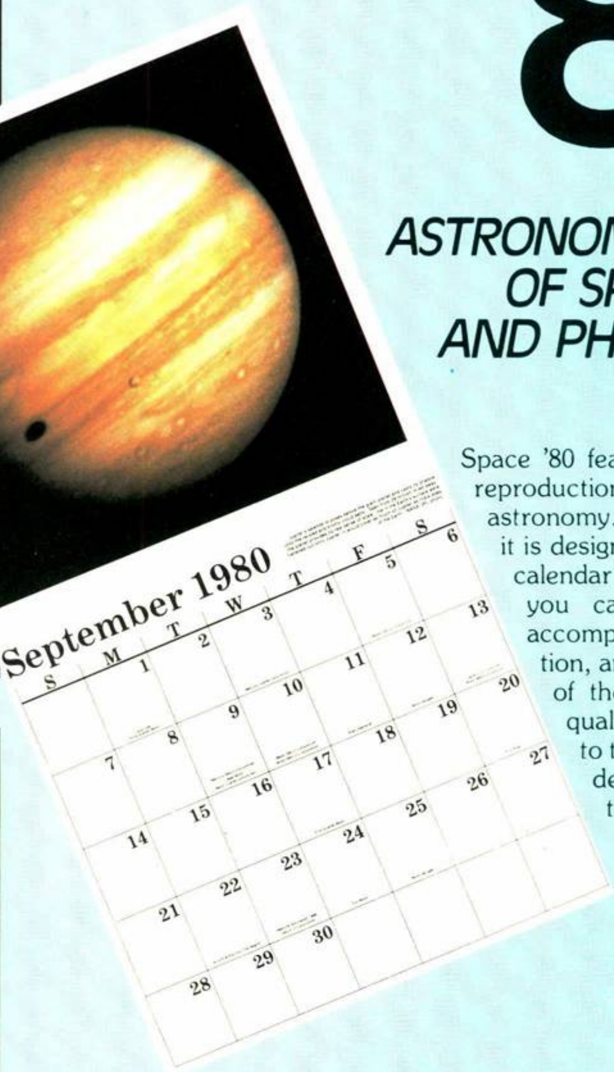

September 1980

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Cover: The dome of the Anglo-Australian telescope is seen silhouetted against trails of stars circling the pole in this eight-hour exposure. Unlike the northern hemisphere, the south has no bright star like Polaris to mark the celestial pole. In this issue, ASTRONOMY presents more fantastic photographs of the southern hemisphere's celestial objects. Facing page: Color negative film records, in glowing pastel shades, the peculiar galaxy NGC-5128, also known as the radio galaxy Centaurus A. Photos copyright © 1979 Anglo-Australian Telescope Board.

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Southern Skies Explored

by David Malin

Innovative photographic techniques developed in Australia result in images of unparalleled accuracy and beauty, such as this view of the magnificent Tarantula Nebula (also called 30 Doradus) in the Large Magellanic Cloud. The largest diffuse nebula known, the Tarantula lies nearly 200,000 light-years away, yet is invisible to the naked eye. Photo copyright © 1979 Anglo-Australian Telescope Board.

Astronomical photography with a large modern telescope is an inviting proposition at any time, but when the telescope is on a dark site in the southern hemisphere, the prospect is truly exciting. It was with these thoughts in mind that we at the Anglo-Australian Observatory investigated the use of color films for direct astrophotography with the newly commissioned 3.9-meter (150-inch) Anglo-Australian telescope (AAT) and the U.K. Schmidt Research Council's 1.2-meter (48-inch) Schmidt telescope both situated on Siding Spring Mountain near Coonabarabran, New South Wales.

Using Color Negative Film

But why commercial color negative film with all its attendant problems? Why use materials known to suffer from color balance and reciprocity problems during long exposures? And why negative film rather than transparency materials which give a finished result after processing without a further printing stage? The answers are quite simple. We had to use what was available, both from the photographic supplier and in our own laboratories.

In addition, color negatives have two important advantages for the kind of work we had in mind. First, shifts in color balance, seemingly inevitable with long exposures, can be easily corrected during the printing stage. This is much more difficult with transparency materials, and we did not want to lower the light-gathering power of our telescopes by making exposures through color-correcting filters.

And second, negative films have a greater dynamic range, important in astrophotography where very faint and very bright objects appear together in the same field. Exposures aimed at recording the faintest features are often enough to burn out the brighter parts of the image on transparency materials. With negatives, careful printing can retrieve much more information — even in badly overexposed regions.

Against these advantages, we were aware that all color films have a blind spot in the blue-green part of their spectrum. Of little consequence in terrestrial photography, this region happens to lie where a bright emission line from ionized oxygen is found in many gaseous nebulae, and we knew its absence in our pictures was unavoidable.

The type of film we finally used was, in a way, already decided for us. Of the 60 or so color negative films in the *British Journal of Photography*'s list of World Color Films (February 6, 1976), only five are available in 8" x 10" sheet form and only two of these are readily available in Australia — Kodak Vericolor Type S and Type L. The large format was chosen to cover as much sky as practical on both the AAT and U.K. Schmidt (1° x 0.8° and 4.75° x 3.75°, respectively). Additionally, it is the largest size handled by Sydney's commercial color processors.

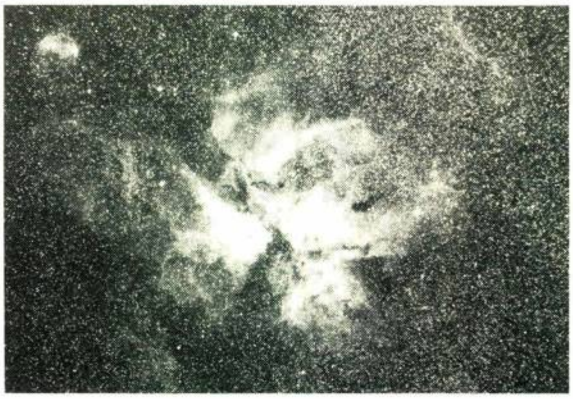
Initial laboratory experiments using long exposures of color patches and grey scales showed us that with a 20-minute exposure, Vericolor Type S (designed for short exposures in daylight) was only slightly slower than Vericolor Type L (intended for long exposures in tungsten light) and that the color shift due to reciprocity failure was small and correctable. We decided therefore to use the short-exposure material (Type S) in a series of tests to increase the film speed by push processing. We were able to double the effective film speed by increasing the first development time from 3½ to 4½ minutes. The speed increase was accompanied by a small but definite lowering of contrast and color saturation. A fourfold increase in speed, with a first development time of six minutes in the C41 process gave unacceptably flat and colorless results. We therefore adopted the two times (that is, one stop) push process as standard for all our negatives to give consistent printing characteristics. (All the experimental exposures and subsequent telescope exposures were processed by a commercial laboratory in Sydney and we are particularly grateful to John Palmer of Color-Teknik for his valued assistance in this project.)

Making the Exposures

For exposure, the unexposed film was either stuck or taped onto conventional glass plates and loaded into the telescope in the normal manner. To eliminate ultraviolet light, a Schott GG385 or 395 filter was used and the telescope focus adjusted to allow for the thickness of the film. As you might imagine, with demand for the AAT five times oversubscribed, time for our color photography was difficult to obtain. We were fortunate, however, in operating a service photography program, designed to fill the need for occasional plates for British or Australian astronomers. This service has proven to be very popular and one or two moonless nights per quarter are reserved for taking deep (long-exposure) plates

An exploding star produced the strange planetary nebula NGC-6302 in Scorpius shown opposite. The brilliant red glow of nitrogen and ionized hydrogen contributes to this vision of celestial violence captured on color negative film. Photo copyright © 1979 Anglo-Australian Telescope Board.

Color negative film in the 48-inch U.K. Schmidt telescope recorded the tangled wisps of the Eta Carinae Nebula in great detail. One of the most glorious regions of the southern Milky Way, this vast nebula harbors one of the strangest stars in our galaxy: Eta Carinae itself, which in 1843 was the brightest single object in our galaxy. Photo copyright © 1979 Anglo-Australian Telescope Board.



for a wide variety of projects. The color photographs were generally taken at the end of a session when there was insufficient time for another deep plate. Exposure times were usually determined by the arrival of twilight rather than in a rigorous scientific fashion. A similar procedure was adopted for the U.K. Schmidt, where the deep southern sky survey takes precedence over all other activities, including color photography. (See "U.K. Schmidt Pictorial," ASTRONOMY, December 1978.)

Because of the limitations on time available, we generally chose subjects where we knew we could obtain a result; hence all our pictures are of the brighter, better known objects. Exposures were always too short to record much contribution from the sky background which greatly simplified subsequent printing operations — we made the sky a dark neutral grey in our prints and found that this gave a very satisfactory balance for all the other colors. This is the astronomical equivalent of including a neutral color guide in the picture — good practice in any form of color photography.

The Objects

Centaurus A is the nearest strong radio source outside our own Galaxy. It appears as a large elliptical galaxy divided in two by a finely structured dust lane. Light from the center of the galaxy is reddened as it passes through the dust, a feature clearly visible in this 45-minute AAT exposure. Clouds of blue stars have been formed relatively recently on the upper and lower ends of the dust lane and are seen as a color contrast against the yellowish older stars which form the bulk of the galaxy. This enigmatic object radiates prodigious amounts of energy in the X-ray, radio, visible, and infrared regions of the spectrum and 25 years after its discovery as a radio source, it is still the subject of intensive study by southern hemisphere astronomers. The giant dust clouds mask the violent nucleus of the galaxy which some astronomers suggest contains a black hole.

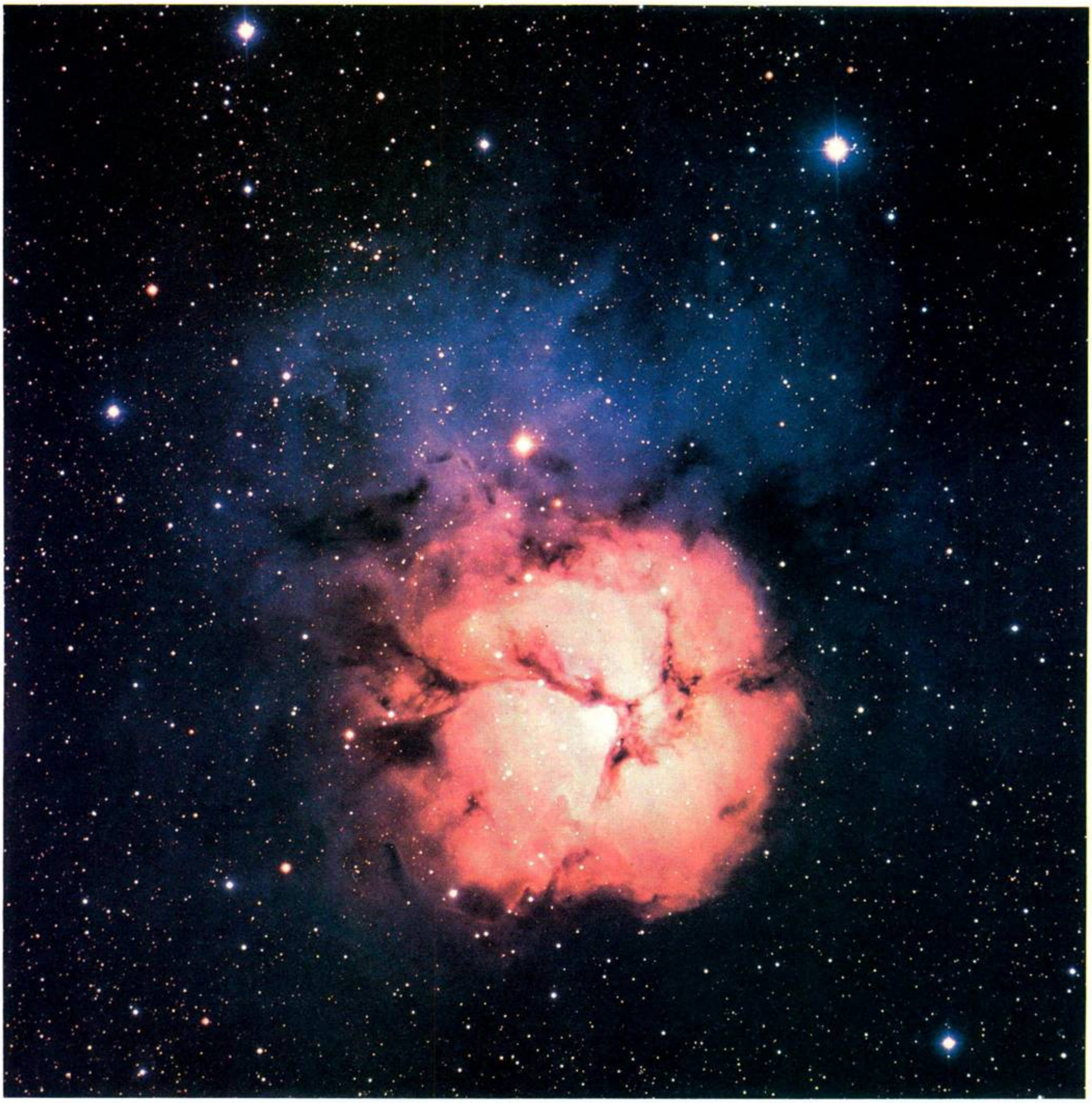
Prominent in the far southern sky are two fuzzy patches of light, apparently unconnected to the Milky Way and known as the Magellanic Clouds (after the Portuguese navigator Magellan who first described them). These objects are small nearby companions of our own Galaxy and are the subjects of intensive interest to southern observers. The bright Doradus Nebula is a massive cloud of ionized hydrogen clearly visible in small telescopes at the eastern end of the Large Magellanic Cloud. The many hot young stars seen in this photograph are evidence of relatively recent star formation in the region. To the south are smaller patches of nebulosity, one of which has very recently been detected as a source of X-rays (LMC-X1). This picture was taken on the 1.2 m U.K. Schmidt telescope on Kodak color negative film.

A classical planetary nebula has a spherical shell of gas surrounding the star which ejected it. While many of these are known, most planetaries are in fact either irregular or roughly symmetrical in shape. It is not fully understood why some stars eject a complete shell of gas whereas others, such as NGC-6302 pictured here, are less regular in appearance. The explosion which created this planetary nebula was particularly energetic and very high velocities have recently been found in the gas ejected from the star by John Meaburn of Manchester University (England), using the AAT. The red color is due mainly to nitrogen gas together with some hydrogen ionized by ultraviolet light from the central star which lost a fraction of its mass in the outburst.

The beautiful southern spiral galaxy M-83 (NGC-5236) is shown in this article on a 45-minute exposure taken at the f/3.3 prime focus of the 3.9 m Anglo-Australian telescope on Kodak Vericolor (S) film. This fine galaxy is well known for the relatively large number of supernovae discovered there (on the average one every 15 years) — more than in any other galaxy. Very many red hydrogen emission regions and nearby groups of young blue stars can be seen in the two spiral arms. In contrast, the older stars which form the nucleus of the galaxy are yellowish in color and are of the same type as those which comprise elliptical galaxies.

The magnificent Carina Nebula at the heart of the southern Milky Way is shown in its full glory in this 45-minute exposure made on the 1.2 m U.K. Schmidt telescope at Siding Spring, Australia. This picture shows a piece of sky about 2° across, covering about twelve times the area of the full moon. At a distance of 9100 light-years, the nebula contains two of the most luminous and massive stars in our Galaxy. In the central region, near the small Keyhole Nebula lies one of these, Eta Carinae itself. This strange energetic object was as bright as Sirius when it was first observed by Herschel in the 1830s but has now faded to 7th magnitude. Thick lanes of dust span the face of the

Spinning serenely in the depths of cosmic space, the spiral galaxy M-83 in Hydra reveals its beauty to the 150-inch eye of the Anglo-Australian Telescope. Photos copyright © 1979 Anglo-Australian Telescope Board.



The brilliant red of hydrogen emission combines with the blue of reflected starlight to produce the glorious beauty of M-20, also known as the Trifid Nebula. Proper color balance on the print is especially easy to achieve with color negative film. Photo copyright © 1979 Anglo-Australian Telescope Board.

nebula and further redden the ruddy glow of hydrogen ionized by the hot bright stars within it.

The well-known Trifid Nebula (M-20, NGC-6514) is a prominent feature of the southern Milky Way. It combines red emission with blue reflection nebulosity to form an object which is an astrophotographer's delight. About 4500 light-years away and 20 light-years wide, the emission nebula is crossed by the three dark dust lanes which give the object its name. Where these dust lanes meet are a group of very bright massive stars whose radiation is sufficient to ionize the hydrogen gas surrounding them. To the north, another bright star illuminates a cloud of dust to produce the blue reflection nebulosity. This whole area of the Milky Way, which includes the Lagoon Nebula, is a region where stars are presently being formed from the plentiful gas and dust stirred up by prehistoric supernovae. The picture was taken on the 3.9 m Anglo-Australian telescope.

The pictures accompanying this article are only a sampling of what can be done with these techniques. Properly employed, common color negative film can be used to produce astronomical photographs of unparalleled beauty and usefulness.

David Malin, research photographer at the 3.9-meter Anglo-Australian telescope, is also the author of "Exploring the Image," ASTRONOMY, November 1979. Apart from photography, his research interests include supernova remnants and the structure of radio galaxies.

FOR THE LOVER OF FINE INSTRUMENTS . . .

the Questar family of telescopes

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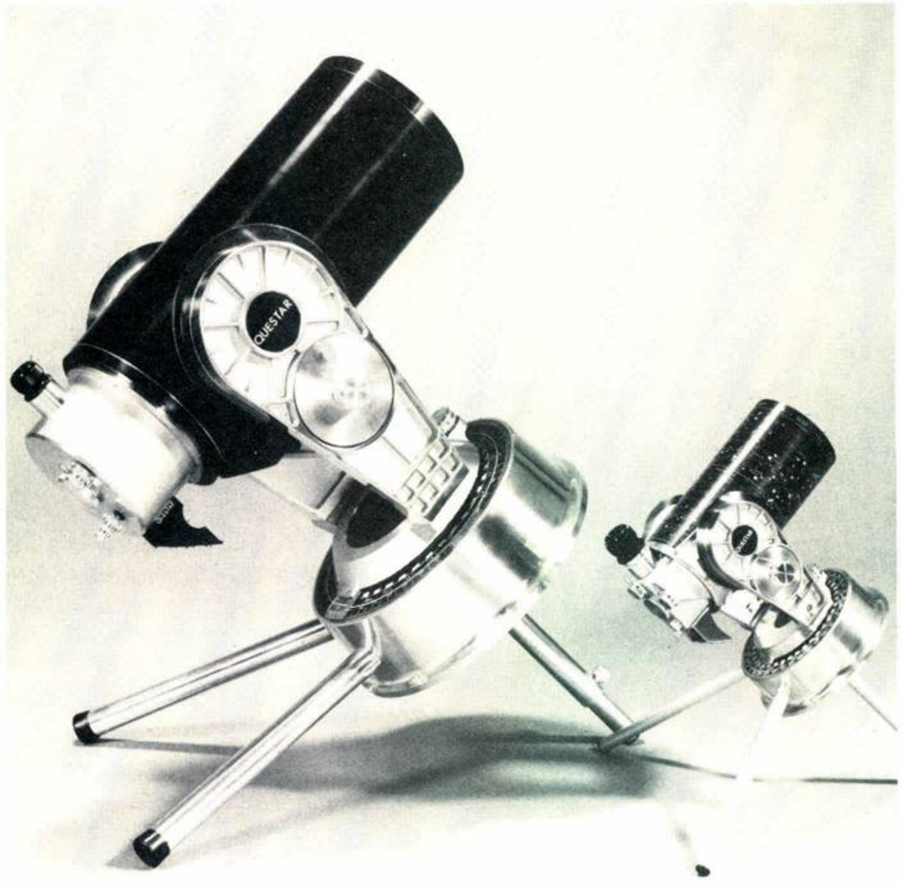

Because Questar's inventor loved fine instruments, he designed Questar for himself. He had begun dreaming about the kind of telescope he someday wanted to own, long before such a thing was considered a possibility.

To begin with, of course, there was to be a set of optics so fine that no amount of money, time, or human effort could improve upon it. Second, since he believed that the use of a telescope should not be a difficult physical chore, the size was extremely important: it should be easily portable. Preferably it would be small enough to be used on a table, where a person could sit in a relaxed position to observe and be able to have a writing surface at hand. And since he planned to carry it in his travels, it would be packaged handsomely in a piece of leather luggage.

Third, the accessories which were necessary for the enjoyment of a telescope were to be built in and should have fingertip controls within easy reach.

Fourth, the mechanical design must incorporate a means of putting the telescope into its polar equatorial position at a moment's notice and without the need of a separate tripod.

Fifth, the versatility that he visualized would make this instrument equally suitable for nature studies in the field. It also should be able to focus on close objects, which no other telescope in the world could do.

Sixth, the design must be photovisual so that he could record on film whatever these superior optics would present to the eye.

And finally, the instrument must be of rugged construction and vibrationless, without the aggravating oscillations of long-tubed conventional telescopes.

* * *

As we have said, this was the dream, but one lacking the possibility of fulfillment within the state of the art at that time. However, in the 1940's an important discovery in optics occurred. When Maksutov published, in the *Journal of the Optical Society of America,* a paper on his mixed lens-mirror, or catadioptric, system, it was immediately apparent to Questar's designer, Lawrence Braymer, that this break-through in optics would make possible a miniaturized version of the astronomical telescope which he had for so long wanted to build.

The Questar telescope reached the market in 1954: 3.5 inches of aperture with a 7-foot focal length in a sealed tube only 8 inches long, and with all the built-in conveniences that he had planned. These included a wide-field finder, power changes without changing eyepieces, smooth manual controls in altitude and azimuth, safety clutches, setting circles, a sidereal clock, and synchronous motor drive. Moreover, a totally safe solar filter had become an additional feature created for the solar observer.

Included, also, were legs for a tabletop polar equatorial position; and as the design had progressed it had come to include two other conveniences: a map of the moon anodized on the barrel and a chart of the stars anodized on an aluminum sleeve to slip over the barrel. The chart revolves for monthly star settings and slides forward to serve as a dewcap. Both charts make other maps unnecessary during observing sessions.

Most remarkable of all were the optics—this was a system so fine that it has consistently delivered resolution surpassing its theoretical limits. Throughout its subsequent history, the care and precision with which every set of optics has been made and star tested has earned for the Questar telescope its reputation as the finest in the world.

* * *

Other Questars have followed over the years—the Seven, which is twice the size of its world-famous predecessor, has twice the resolving power and four times the light grasp; and more recently, the Questar 700. The latter is an f/8 telephoto lens for the photographer, and *Modern Photography* has simply called it "the best." The 700 guarantees perfection and flatness of field from edge to edge; also, precise focusing from infinity to 10 feet with a single turn of the focusing ring.

A newcomer to the fleet is the Questar 12, which is Questar Corporation's answer to the problem of an important telescope for the university and for special industrial applications, as well as the ultimate in a personal telescope.

We always say that when you buy a Questar telescope you get the whole observatory. For example, the 3 1/2 in its fitted case contains all that you need to enjoy the earth or skies, day or night. Your Questar need never be idle, and you can carry it with you wherever you go. In a recent letter a Questar owner called it "an enchanting companion."

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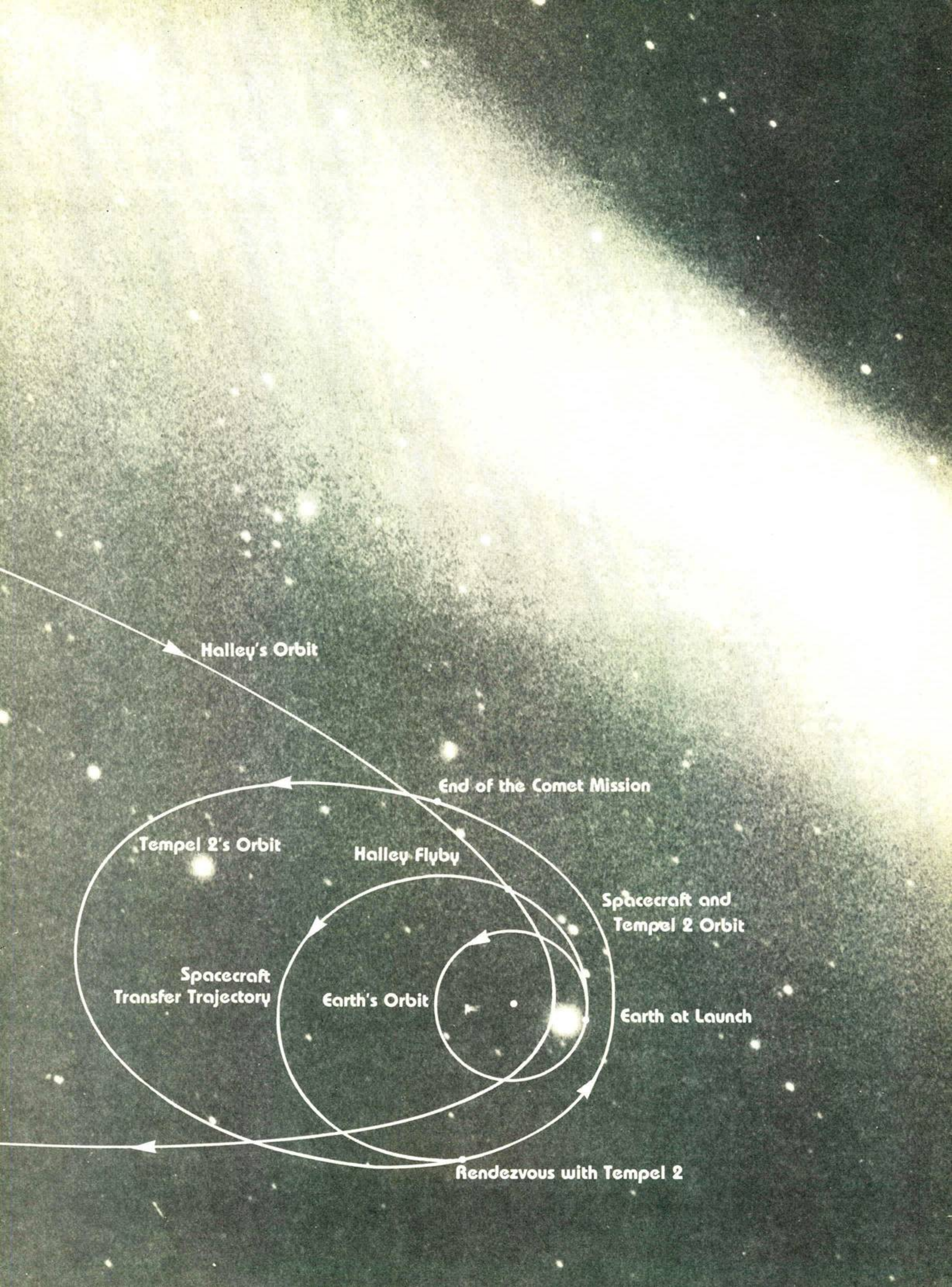
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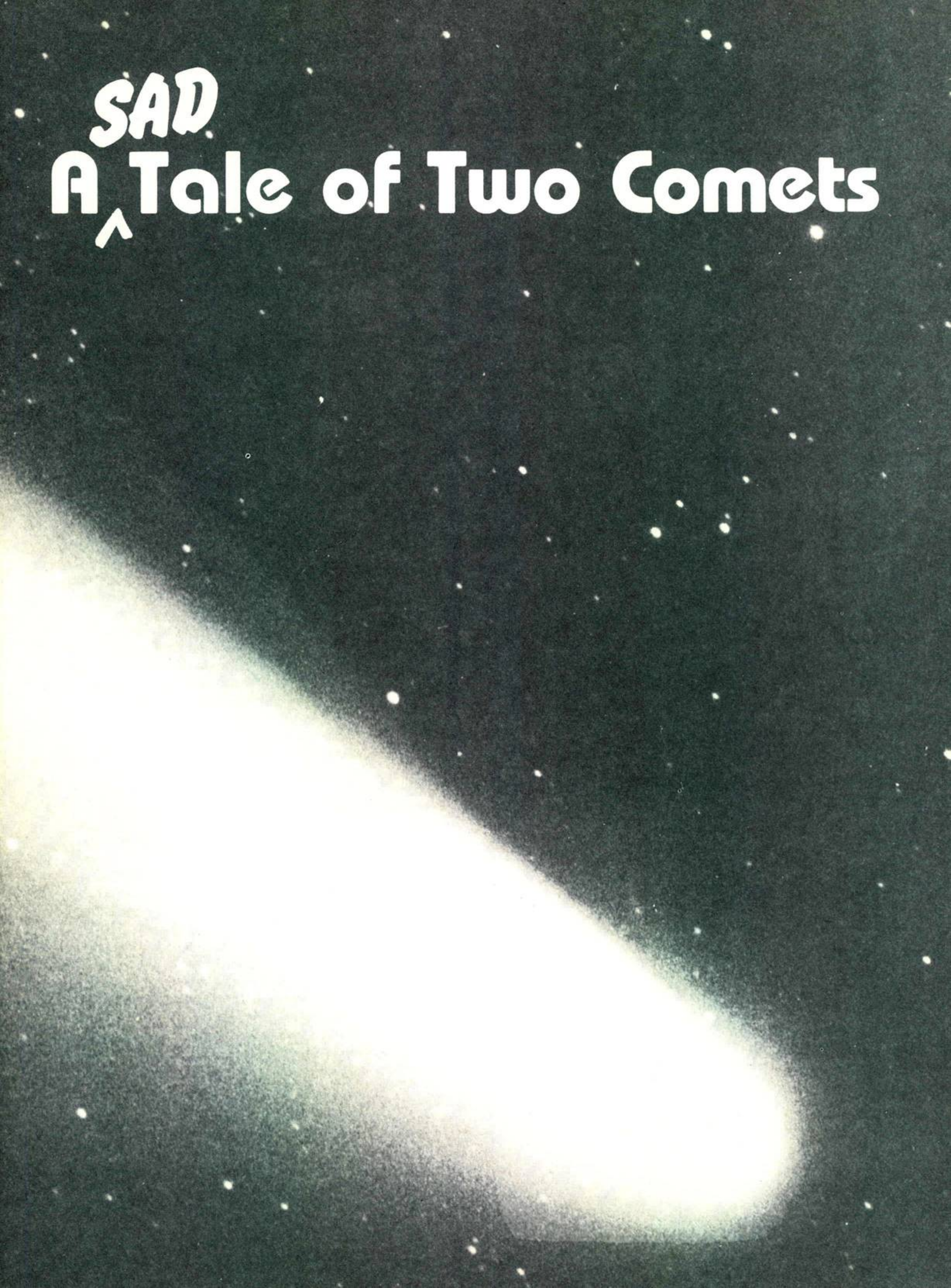
A SAD Tale of Two Comets



The next decade offers an opportunity to conduct a fantastic voyage to two comets. To be launched in mid-1985, the mission plans call for a close flyby of comet Halley (the comet that awed your grandfather during its 1910 apparition), followed by an intensive investigation of comet Tempel 2 (actually flying with this comet for a year, the mission perhaps ending by landing on its surface).

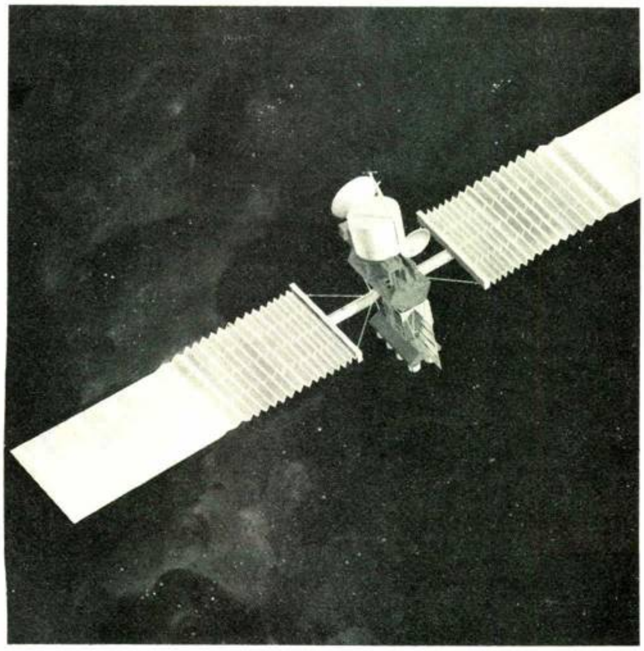
But why would we want to investigate a comet?

Comets are the raw stuff of the solar system. They lie far beyond the most distant of the planets in a tenuous swarm, slowly circling the Sun. Astronomers estimate there are 100 billion of these tiny icy bodies, each only a few kilometers across, preserving an original and unmodified sample of the primordial nebula from which the Sun and planets formed. While a comet remains out at the fringes of the solar system, it is inaccessible. When perturbed from its placid existence by the random gravitational kick of passing stars, however, a comet can fall into the inner solar system, heat, throw off gas and dust, flare into brief glory, then retreat once again into cold, deep space.

Of all the solar system bodies known, none is more pristine than a comet. Nowhere else in the solar system is such a perfect record of earliest time preserved. A journey to a comet is a journey back through time, a journey to examine materials that have remained unchanged since the birth of the Sun and planets.

The oldest rocks we find on Earth, modified granites in northern Canada and Greenland, date back three and a half billion years. These rocks preserve records — but distorted records — of an ancient Earth smashed and bombarded by giant meteors, a hot cauldron of chemical activity. But the oldest Earthly rocks were formed a billion years after the formation of the Earth. They're not the clues to the beginning.

The lunar rocks returned by Project Apollo were older and less altered. The oldest rocks returned from the Moon were about 4.3 billion years old, and formed perhaps a quarter billion years after the Moon. Scientists had hoped to find far more ancient material on the Moon. The extent of ancient lunar heating was an unpleasant surprise, even though it was an important discovery.



Looking back into the depths of time in the inner solar system is not easy. The bodies near the Sun have long been degassed of their icy primordial stuff. Exposed to heat, radiation, mixing, chemical and physical differentiation, high pressures, and violent shock, their lightest elements, hydrogen and helium, have long since blown away into space.

We have only a few meteorites, the baked-out debris of comets, to tell us about the original composition of the solar system, and they have reached us only after a violent passage through Earth's atmosphere.

The bodies of the outer solar system have been less affected: the giant planets still retain their original complements of elements intact. But they've been altered, pressurized and heated, until the original chemistry of the solar nebula is hopelessly lost. Even the small and cold bodies, Pluto and the satellites of the giant planets, have been subjected to the shock and trauma of the planet-building process. They are also terribly remote.

But the comets never grew large, so they escaped the battering jolts of accretion into planetary-size bodies. Remaining small, their materials escaped the pressure and heat of a planetary interior. The Sun never baked away their original atoms. They remained unchanging, frozen in time for five billion years far beyond Pluto in the cold of space.

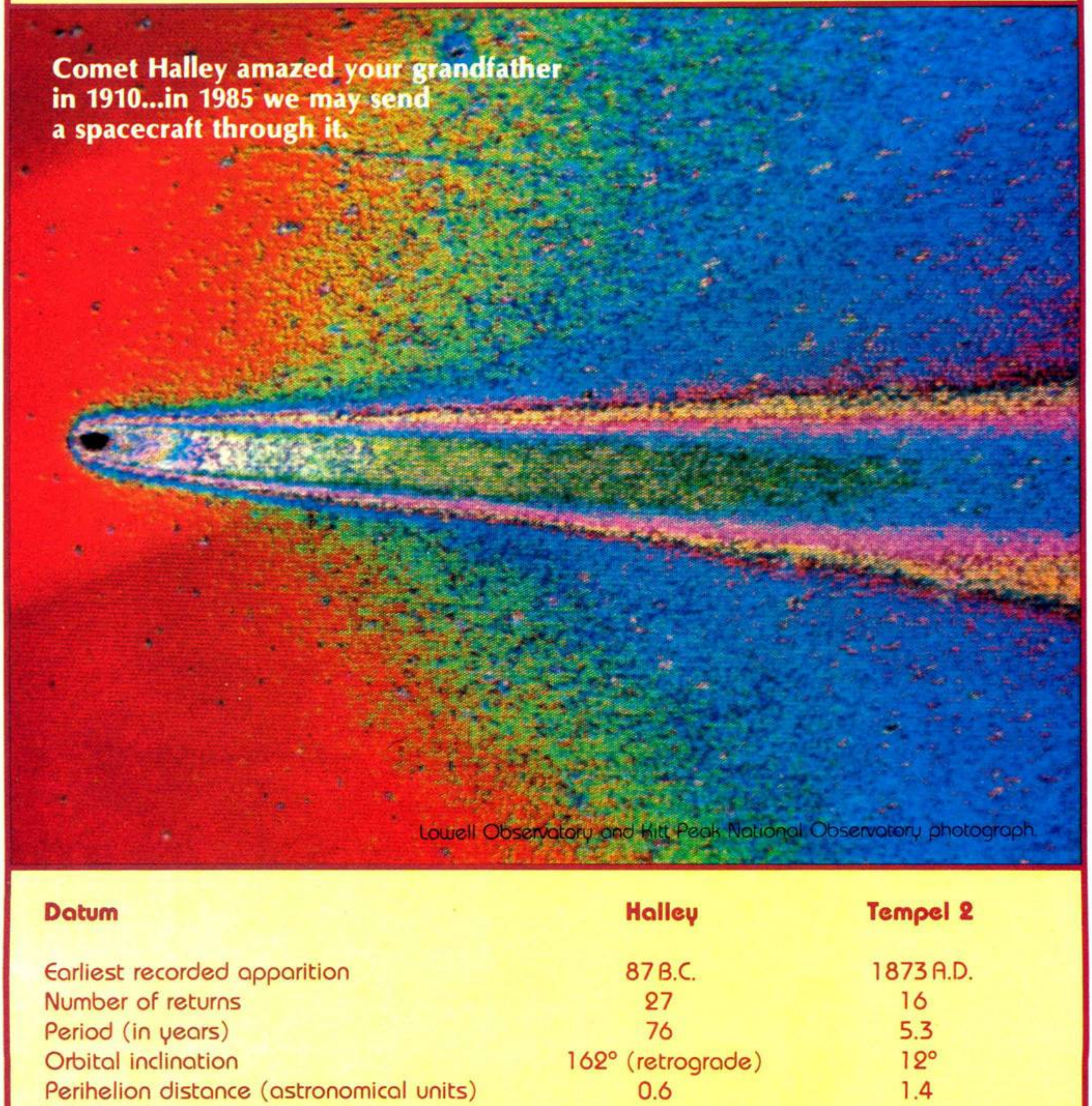
We're not sure where the comets formed. They might have condensed on the fringes of the solar system, where they are now, retaining the characteristics of interstellar dust grains and ices. If this is true, then they will tell us about the composition and conditions in the presolar nebula. Or, they might have formed closer to the Sun, somewhere outside the orbit of Saturn, and subsequently been gravitationally ejected from the solar system. If this is true, then comets will tell us about the tiny planetesimals, bodies that astronomers think coalesced to form the planets.

We wouldn't know that the comets were there at all if an occasional one didn't pass through the inner solar system. And we couldn't hope to study them in this century if they all appeared unexpectedly out of dark space for a brief flash of glory. Some comets pass too close to one of the planets and don't escape again. Their orbits become closed; they may skim back out to the edges of the solar system, but must once again fall back. They circle, passing the Sun again and again and again, in a predictable path. It is these "periodic" comets that we can hope to reach with twentieth century technology.

Once captured, a comet doesn't last more than a few hundred orbits. At each passage its ices melt,

NASA plans to fly this unusual spacecraft to two comets. The three-part craft consists of the solar electric propulsion system that flies the craft to the comet and its solar-panel "wings", a cylindrical probe to be aimed into the very heart of comet Halley, and a package of instruments, cameras, and communicating gear to return scientific data. NASA illustration.

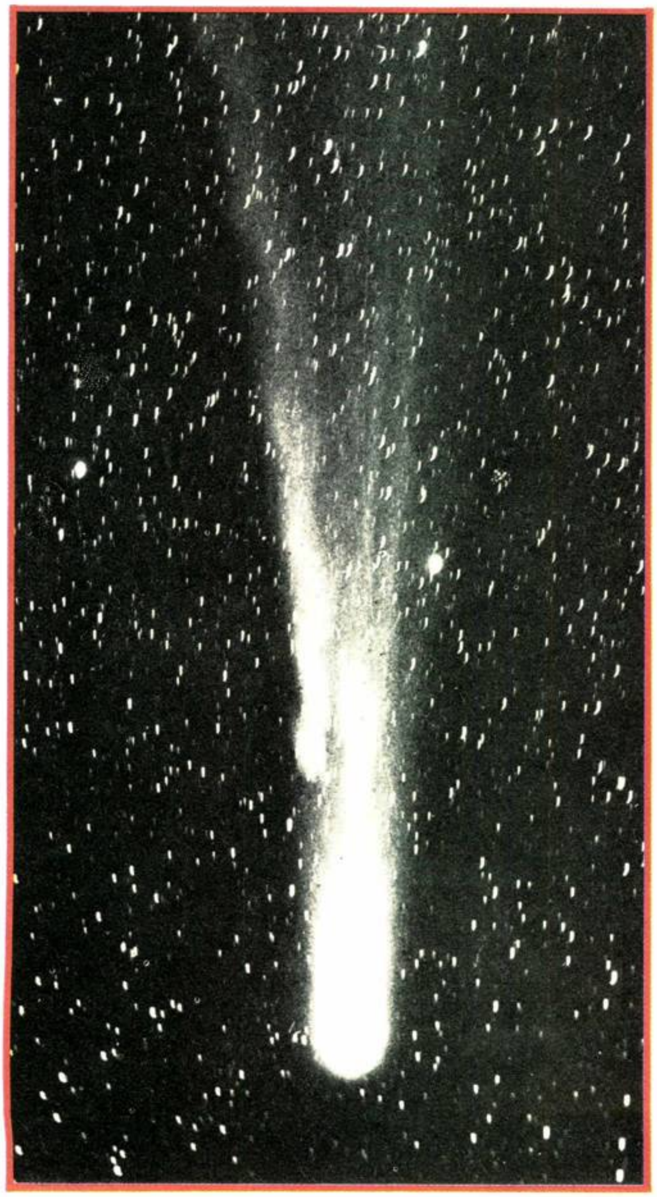
Comet Data Table



Comet Halley amazed your grandfather in 1910...in 1985 we may send a spacecraft through it.

Lowell Observatory and Kitt Peak National Observatory photograph.

Datum	**Halley**	**Tempel 2**
Earliest recorded apparition	87 B.C.	1873 A.D.
Number of returns	27	16
Period (in years)	76	5.3
Orbital inclination	162° (retrograde)	12°
Perihelion distance (astronomical units)	0.6	1.4
Diameter of nucleus (kilometers)	5	3
Diameter of nucleus (miles)	3	2
Maximum diameter of coma (kilometers)	400,000	100,000
Maximum diameter of coma (miles)	250,000	60,000
Tail	bright, active	none observed
Gas production rate (Tempel 2 = 1)	700	1
Brightness (Tempel 2 = 1)	100	1
Date of perihelion	2/09/86	9/17/88
Date of encounter	11/28/85	7/19/88 - 7/14/89



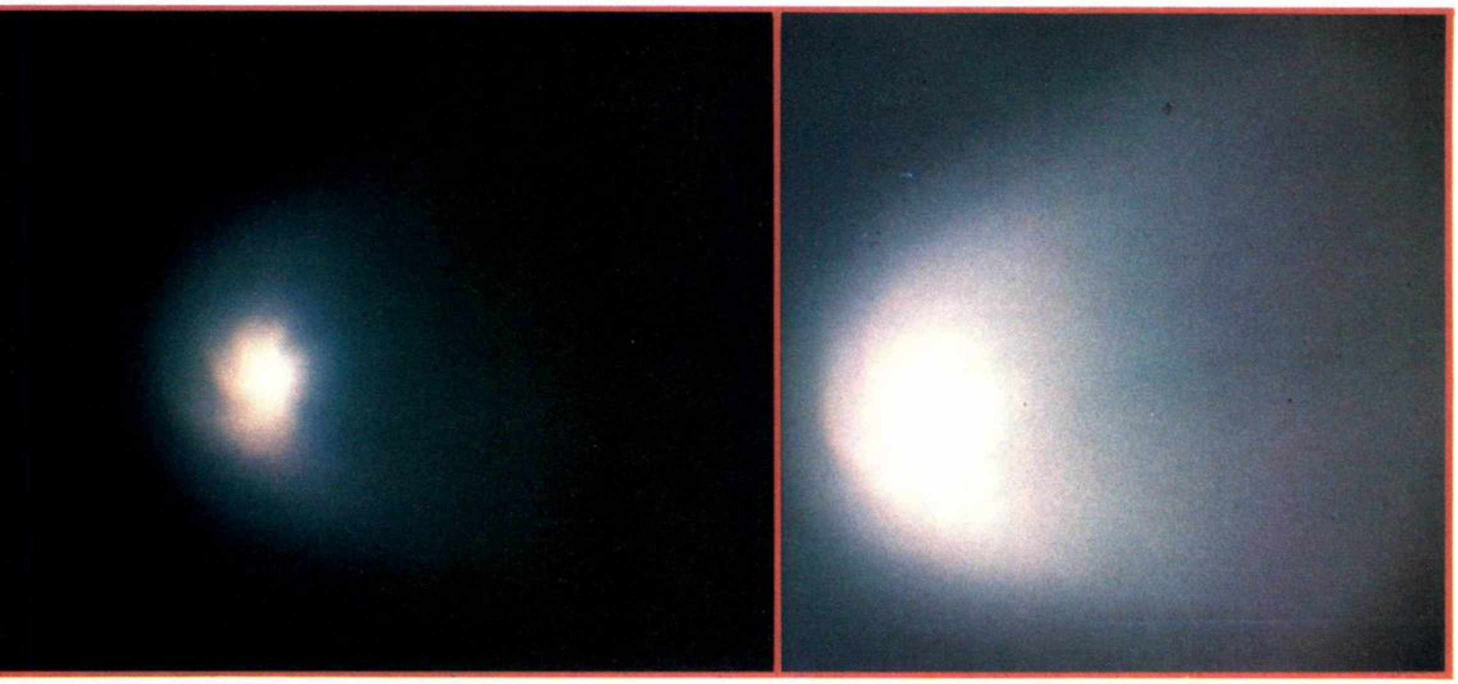
The comets and tails of comets are filled with complex and irregular structures that astronomers suspect are related to the structure and composition of the cometary nucleus. Above: The photographs of comet Bennet 1970, all made on the same night, show jets and fountains of gas in the coma. The shortest exposure (at left) shows only the inner coma; longer exposures show gases flowing outward in a spiral pattern. Lunar and Planetary Lab photographs. Left: Events in the comet affect the tail, too, producing "kinks" such as the one recorded in comet Halley's tail on June 6, 1910. Lick Observatory photograph.

evaporate, boil away, stream off into space as a spectacular tail until, eventually, nothing remains of it but an orbiting cloud of rocky debris. Comet Halley is especially interesting because it is the only periodic comet known that is still "young" enough to act like a still-fresh comet.

The craft that NASA proposes to use to explore two comets in a single mission is an ungainly affair, a creature of deep space itself. Its two 35-meter-long solar panel "wings" will provide power for its unique propulsion system to warp the spacecraft's orbit out to the first comet, then on to the second.

The craft will consist of three parts: the solar electric propulsion system (SEPS) which flies the cameras and scientific instruments out to the comets, a special probe to be aimed into the very heart of comet Halley, and the rendezvous spacecraft which will fly "in formation" with comet Tempel 2 for a year, orbit it at close range, and perhaps, at the end, actually land on the cometary nucleus.

The mission has already begun. Astronomers and NASA scientists have already been meeting for several years working out the details of a mission. They've examined all the comets that might be candidates for comet missions, and run hundreds of possible orbital interceptions on the big computers at JPL. Engineers have tested the ion propulsion engines which make possible the comet interception for thousands of hours, and have even flown prototypes in space.



The mission depends on comet Halley. Halley is unique: if we want to study a large, active comet, Halley is the only choice. Halley will be here in 1986 and will not return until 2061. To meet the inexorable deadlines imposed by celestial mechanics, the spacecraft must leave Earth orbit in July 1985 and fly past Halley in November.

The mechanical and engineering requirements for the spacecraft have been worked out. The technology has been tested — earlier missions have flown similar scientific instruments with spectacular success. Top NASA officials are behind the mission. All that's needed is the money to do it.

To meet the July 1985 launch goal, work must begin on the ion propulsion engines in fiscal year 1981, and work on the cameras and scientific instruments in fiscal year 1982. (The federal FY 1981 runs from September 1980 to August 1981.)

If the mission receives a go-ahead, the launch into Earth orbit will be aboard the Space Shuttle in July 1985. Then on August 1, 1985, it will boost out of Earth orbit powered by the twin-stage Interim Upper Stage rocket. After burnout, the rocket will separate, and the spacecraft will unfold itself. Two giant solar panels 4 meters wide and 35 meters long (12′ x 116′) will unfold to provide 30,000 watts of power for the ion propulsion drive.

Solar electric propulsion engines, the "ion drive," have been developed by NASA as a primary spacecraft propulsion system especially compatible with Shuttle-launched space probes. On the Halley/Tempel 2 mission, the system, called the SEPS, operates by electrically charging a dense vapor of mercury. An electric field then accelerates the vapor to a very high exhaust velocity. While the thrust is not very great, the engines operate continuously for years at very high efficiency — ten to a hundred times the efficiency of chemical rockets — while deriving the energy for propulsion from the Sun.

The ion propulsion system will run almost continuously during the mission to execute the

Why Halley? Why Tempel 2?

Comets pose difficulties for space missions. The youngest, brightest, most active, and most interesting comets appear suddenly, flash through the inner solar system, and retreat into deep space too quickly for a mission to them to be planned and flown. An ideal comet for a science mission must strike a balance between the predictability of its orbit (that is, it must be a periodic comet) and its "freshness."

In these respects, comet Halley is ideal. It is still "fresh." Although it has been seen at 27 apparitions in the last 2000 years, it still shows a broad range of active cometary behavior. Halley is also accessible; in fact, it is the only bright periodic comet available before the end of this century. Unfortunately, Halley has a retrograde orbit (i.e., it orbits the Sun in a direction opposite that of the planets), so that any flyby encounter we could launch now must occur at very high relative velocity.

Tempel 2 is not an active comet — it isn't even known to have a tail. But Tempel 2 is a good compromise between "freshness" and "mission safety." Of the five comets that could be reached through the year 1993, three are too faint to be interesting or too erratic to be safe. Only two offer good scientific potential: Tempel 2 and comet Encke. While these two are about equally interesting scientifically, comet Encke is much harder to reach, thus making the scientific payload that could be flown to it much smaller.

difficult maneuvers necessary to swing the spacecraft past Halley and then on to a rendezvous with Tempel 2.

Four months after launch, on November 28, 1985, the spacecraft will pass comet Halley. Powerful cameras aboard the main spacecraft will take photographs and spectra of Halley's coma and tail as the spacecraft and comet converge at 200,000 kilometers (125,000 miles) per hour. Shortly before encounter the main spacecraft will maneuver to avoid passing closer than 100,000 kilometers (60,000 miles) from Halley — but it will release a 400-pound probe aimed at the nucleus of Halley.

The probe is an interplanetary symbol of international cooperation. It will be designed and manufactured by the European Space Agency in cooperation with NASA. The probe will fly through the dangerous dusty region close to the nucleus, frantically sampling the dust, neutral gas, ionized gas, charged particles, magnetic fields, and plasma waves of Halley's coma during the too-brief encounter. The probe will fly through the inner coma in less than a minute. One picture — all there's time for when the probe passes the nucleus — will be taken. The extremely high flyby speed means that everything will be over almost before it begins.

Comet Halley will greet the probe some 73 days before it reaches perihelion, at a distance of 140,000,000 miles from the Sun. Halley will be reacting — for the first time since 1910 — to the solar presence. Even at this distance from the Sun, there will be streamers of gas spewing into space, concentric shells of gas rising out of the coma, and 20,000-mile fans of gas spraying erratically around. The inner coma will be changing on an hour-by-hour, day-by-day basis, showing rapid changes in size, shape, and brightness. It should be exciting.

After Halley encounter, the spacecraft will fly on quietly for 960 days with the SEPS thrusting almost continuously, bringing it around to intercept comet Tempel 2. The spacecraft will go out to the distance of the asteroid belt, departing more and more from the ecliptic plane, as it maneuvers to match its flightpath to the inclined 5.3-year orbit of the comet. And on July 14, 1988, 1080 days after launch, the spacecraft will rendezvous with the comet.

It is important to reach Tempel 2 several weeks before the comet becomes active to examine it as closely as possible before it is altered by solar heating. The spacecraft, equipped with powerful cameras, dust analyzers, neutral and ionized gas mass spectrometers (the "molecule sniffers" that tell us the composition of the gas around the comet), and radar, will pass within 100 kilometers (about 60 miles) of the comet nucleus. Pictures of the nucleus will show objects down to 6 meters (20 feet) across on it.

The mass of the comet, and the safety of the environment around the comet, will be assessed. "Is it safe to stay here?" will be the top question in the mission director's mind. As the comet heats and becomes more active, the spacecraft will back away to a safe distance, now using its ion thrusters for precise control and positioning. Tempel 2 is bound to be a much safer comet than Halley because it's smaller and about 100 times less "active," but early in the mission, the astronomers will be cautious.

News Flash:

Two Comet Mission in Trouble

Aviation Week and Space Technology, an aerospace industry magazine, reports that the federal Office of Management and Budget has killed the Comet Halley/Tempel 2 Mission by cutting the funds in NASA's FY 1981 budget requested for development of the Solar Electric Propulsion System. Without the SEPS, the Two Comet Mission could not be flown. Cancellation of this important mission will be a major blow to solar system exploration.

NASA Administrator Robert Frosch has appealed to President Carter to reinstate the mission. At present, a decision is still pending.

Alternative comet mission strategies, such as a separate Halley flyby and a later comet rendezvous mission, would provide inferior science results and cost more.

As Tempel 2 passes through perihelion (closest approach to the Sun) at 128 million miles, the spacecraft will photograph, in great detail, the changes in the nucleus. We'll watch gas streamers form and die away, fissures and cracks open on the surface, perhaps even see pieces breaking away. The entire mission will produce 40,000 pictures — many of them during this phase.

The spacecraft may also be flown around "behind" the comet and through its tail. Then, as Tempel 2 recedes from the Sun and activity dies down again, the spacecraft will cautiously approach the nucleus again, closer and closer, collecting dust, measuring temperatures, and "sniffing" the gases of the coma. Finally, when it becomes safe to try, the spacecraft will go into orbit around the nucleus at a distance of about 10 kilometers (6 miles).

From that distance, the cameras will photograph the nucleus in exquisite detail, recording structures down to 10 centimeters (4 inches) across. One thing they'll be looking for is a safe place to land. Meanwhile, radar, X-ray, and gamma-ray instruments will probe the structure and composition of the nucleus, looking into its interior, measuring the abundances of the heavier elements and metals that might be present in a rocky core.

Closer and closer the spacecraft will approach until, taking a chance, it will contact, and possibly land on, the surface. If the spacecraft can remain in radio contact with Earth after this encounter, astronomers will learn a lot about the hazards of landing on a comet for future nucleus-landers and sample-and-return missions. And we'll know that, at last, we've touched a comet.

Comet West, a brilliant morning comet in early 1977, was a young comet making its first passage by the Sun. Unlike comet Halley this comet will not return to the solar neighborhood for thousands of years. Halley is a young comet, still fresh, but doomed to return again and again at regular intervals, and an ideal target for a mission to a comet. Photograph by Rev. Ronald Royer.

ASTRONOMY
FORUM

A Gathering of Astronomers

Once a year astronomers particularly interested in the solar system meet to present scientific papers and discuss among themselves the state of their science and their understanding of the nature and origin of the planets. Of course, a great deal more — upcoming missions, jobs, gossip, funding for projects, new equipment — is discussed too. Late last October, the planetary scientists met in St. Louis. ASTRONOMY'S editor, Richard Berry, attended this meeting, as he has for the last four years. Here is his report:

Considering that the Space Program is in deep trouble, the astronomers were in a pretty chipper mood. The triumph of the twin Voyager flybys and the extraordinary performance of Pioneer 11 at Saturn seemed to take the edge off the scientific desolation they will be facing during the early 1980s. After the Voyagers fly past Saturn, one in 1980 and the other in 1981, there will be no more scientific results from the planets until the 1986 Galileo mission to Jupiter. And right now, there are no other planetary missions funded. In short, America has virtually turned its back on space.

The scientists are probably calm in the face of such gloomy future prospects because they've known it's coming for years. They've seen the new programs delayed, canceled, and backwatered. They've had years to get used to America's "reduced commitment" to space. It's nothing new; it began before Apollo 11 landed on the Moon, and it's gotten steadily worse.

They're pushing now for two major solar system missions during the early 1980s — the Venus Orbiting Imaging Radar (described in the January 1979 issue of ASTRONOMY) and the Two Comet Mission to Halley and Tempel 2. They're also backing another important NASA astrophysics mission proposal — a gamma-ray observatory, which in the words of Frank Martin, acting director of Space Science and Astrophysics, "can do the geophysics of pulsars."

Galileo to Jupiter is, at present, the only mission under development. The VOIR radar mission to Venus, a candidate mission for a start in fiscal year 1981, is going to be "descoped," trimmed to cut costs in the hope of getting it approved. The Two Comet Mission requires 1981 funding for the ion propulsion engines if the technology is to be ready in time for a fiscal year 1982 start on the mission itself. And meanwhile, there's the "Data Gap" — we'll pass 1982, 1983, 1984, and most of 1985 with no new solar system probe results. In late '85, if it flies at all, the Two Comet Mission will encounter Halley. Galileo, if all goes well, might arrive at Jupiter in '86. VOIR may "peel back the clouds of Venus" in '87. Then, in 1988, the Two Comet spacecraft, if it flies, will reach Tempel 2.

"NASA's only got one thing on its mind, and that's getting the Shuttle off the ground before it becomes a national scandal," said one planetary scientist.

"There's no perceived political *advantage* to making new starts (on space missions), and there are no penalties for *not* making new starts," said another.

"Isn't the problem that Joe and Joan Citizen *don't write to their* congressman?" suggested a respected astronomer.

"No, the problem is leadership — at the top level. The Administration doesn't present Congress with an exciting and viable space program," said a NASA official.

"What's really driving us out of business is that damned military program — the MX missile system. It has nothing to recommend it, yet it's going through Congress like a greased pig!"

Clearly the Space Shuttle is one sore point among many. Well behind schedule, yet with no assurance of impending success, the Shuttle's failures have meant that NASA has had to take money from other programs and NASA divisions. The Galileo mission to Jupiter will be delayed at least two years and cost over $100 million more than originally planned because the Shuttle's engines don't deliver the thrust they were designed to. Nor do the heat protection tiles intended to protect Shuttle during re-entry stay properly attached. Failure of a single tile could destroy an entire craft during re-entry.

The shuttle's problems stem largely from building it "on the cheap," eliminating proper testing of components. The fruits of these earlier decisions are catching up with the space agency as small single-component failures damage entire engines during testing. Not only has "cheapening" the Shuttle made it become more expensive, but it may be risky to fly. The matter of safety aboard the Shuttle may be reviewed by the President.

But like it or not, the Shuttle is going to be *the* way — and virtually the *only* cheap way — to put large payloads into space. The military now sees the Shuttle as important to its programs, too. Voicing his fears to other members of the DPS, an astronomer commented, "One thing now driving Shuttle is the military applications — launching things to verify SALT II...."

Sold to Congress originally as an all-civilian venture, NASA enlisted Shuttle support from the Air Force in order to present it as a more attractive package. But military missions, defense communications, and spy satellites will take up many of the available Shuttle launches, perhaps as many as half of them, displacing scientific and civilian launches.

"I'm concerned," said another scientist, "that the Agency will drift to a very high military influence — and we'll *really* lose if the military presence becomes important."

At a special session on the future of NASA's planetary programs, Associate Administrator for Space Science Thomas Mutch (see Forum, September 1979) argued for a more optimistic outlook. "We're engaged in one of the more important activities in our culture: exploration of the planetary system," he said. "There's a lot more data available for analysis than most of us want to admit." These lean years, he said, are a "hiatus in the momentum, but not in science analysis. The real payoff is for those who can put things together" from the data space missions in previous years have generated.

Taking questions on the upcoming "Data Gap," the period in the early 80s when American planetary exploration will virtually cease, Dr. Mutch tried to explain to other scientists less politically minded than himself *why* space has enjoyed so little support:

Q: "Why has that gap formed?"

A: "We have not been successful in getting the necessary new starts."

Q: "But why didn't we have any luck in obtaining new starts?"

A: "It's difficult when OMB announces there will be *no* new

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starts... (Pause) Um, you get more sympathetic when you get to the realities of getting funding."

Another scientist commented: "There's a bad problem in scientific communication in the halls of Congress...," and then clarified, "you have to explain why you need an infrared telescope in space when you've already got an X-ray telescope."

Speaking two evenings later at the inevitable banquet, the man who used to have Tim Mutch's job, Noel Hinners, now director of the Air and Space Museum in Washington, added his insights as a previous administrator: "We're suffering a problem of firsts" — first man on the moon, first pictures of Mars, first flyby of Saturn. "Firsts were easy, but how do we get seconds? Now we're becoming the victim of our own previous success — we're running out of viable firsts."

He proposed to the DPS scientists that funding, and future missions, would depend on their success in a number of areas:

- increasing the sensitivity of Congress to basic science;
- contributing to the popularization of science — by getting the word out to the public;
- accepting the role of exploration, rather than science, as a major reason for the space program;
- looking for alternatives to space probes as ways to obtain data.

"Mars will be explored more for the exploration," he said, "than for the science. You *must* take a long term look at the politics of how science gets done; you *must* get across to Congress and the public."

Meanwhile, the effects of the cutbacks can be heard listening to the casual conversation in the cocktail hour. It's evident that the scientists are responding to the crisis:

"...into research on why the Sahara Desert's expanding...I'm working with Quinn on that."

"I can see we're heading for a lot of work in pollution chemistry..."

"...just getting into smog photochemistry and dynamics of..."

"...will have to be observationally oriented now that we're getting this neat new data..."

"I'm getting out of planetary entirely and into atmospheric physics..."

"I can't push students into planetary work — there's no future in it. I'd rather steer them towards..."

— *Richard Berry*

The Comet Hunters

We're speaking today with Laurel Wilkening, of the University of Arizona, and Joe Cork, of the Jet Propulsion Laboratory, about NASA's proposed comet Halley/Tempel 2 mission. This important mission must receive new start funding for the 1981 fiscal year to successfully rendezvous with Halley in 1985. We'll begin our questions with Prof. Wilkening.

ASTRO: You said earlier today: "We don't know much about comets; in fact we know practically nothing."

LW: That's true — we know very little.

ASTRO: What makes them such difficult objects to study?

LW: They're really small. They're probably only one or two kilometers in diameter — definitely less than 10 km — and from Earth you just can't see something that small. What we see are the large parts — the coma and tail — which develop when a comet comes near the Sun, and they are very insubstantial in terms of mass and secondary because they only arise under the influence of the Sun and the interplanetary medium. We're very ignorant about the nuclei of comets.

ASTRO: So we know *least* about the most important part of a comet. Why do we want to study them?

LW: Well, we think comets, meaning comet nuclei, contain the most primitive material that we can get our hands on. We have good evidence that they're very volatile-rich because when they come in the inner solar system, they give off all the gases we see in the tail — very volatile stuff — that wouldn't be there if they had ever been heated before.

ASTRO: How did you come to study comets?

LW: I guess I got into this whole business because I studied meteorites, and I studied meteorites because they're supposed to be very primitive samples. Meteorites *are* the most primitive samples that we have in our hands now. But comets are pristine, untouched.

ASTRO: So the study of ancient meteoric materials led you toward even more ancient cometary materials?

LW: Yeah, that's what interests me. But you know one of the neat things about comets is that there's a whole range of people interested in them. I'm sort of at one end of the field. I'm interested in the solid stuff, the nucleus and so on, and some early processes in the solar system. But there are lots of people in other fields interested in the comet mission such as physicists who are interested in their interaction with solar wind and so forth.

ASTRO: Joe Cork, what is your role in the comet mission?

JC: I'm the flight system design engineer at JPL, which means I have overall responsibility for the spacecraft, the probe, and the SEPS (Solar Electric Propulsion System) as they are integrated together to accomplish the mission.

ASTRO: Then you must deal both with the scientific people and the engineering people.

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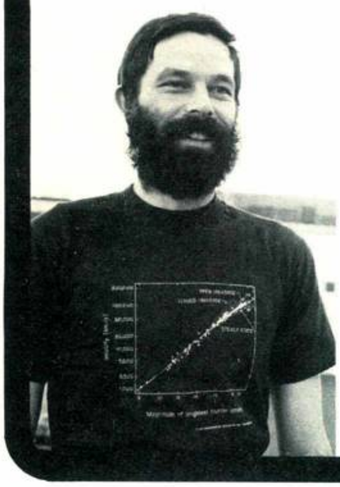

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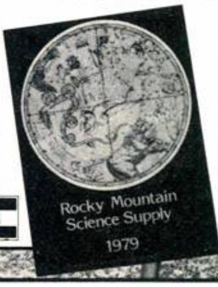

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JC: That's correct. We have specified for us a certain science payload and a set of science requirements. My job is to take those requirements and those prototype instrument designs and integrate them into a spacecraft design. The spacecraft has a lot to do: it must service those scientific instruments and provide the electronics to allow sequencing so that at the appropriate place and time data can be obtained from them and transmitted through the spacecraft computer into the spacecraft telecommunication system and back to Earth.

ASTRO: What science do you expect to accomplish at Halley? What are you going to be trying to do there?

LW: Because Halley is so active in terms of giving off gases and exhibiting all the neat things that comets do — giving off kinky tails and spikes and, you know, lots of excitement — our primary goal there is to try to get a handle on the coma and what's going on in the gas phase — what processes change parent molecules into ions and the things that get swept out into tails, also looking at the dust which forms the dust tails of comets. The probe has been called (and these names always change a lot) a Coma Probe.

ASTRO: I thought you were very interested in the nucleus?

LW: Because it's a flyby, it's quick, and we can't get a good look at Halley's nucleus. The original Halley rendezvous mission — it didn't get funding — would have been better.

ASTRO: What kind of things will you look for in the coma?

LW: One of the things we would like to know is: Are complex molecules there, even in very small amounts. That'll tell us a lot about conditions in the presolar nebula.

ASTRO: The probe actually flies into the coma and "sniffs" the material there?

LW: That's its major job. It's supposed to inhale cometary gas and be zinged by cometary dust which will be analyzed when it impacts the comet dust detector. We also want to get a first look at the nucleus; we hope that we can see the nucleus.

ASTRO: Do you think you're going to lose the probe? Is there any probability of that?

LW: Yes. It will be zapped. It will be aimed at the nucleus but the nucleus is so small I understand that means the probe will be plus or minus 2000 km. Is that still true, Joe?

JC: Yeah.

LW: So we probably won't hit the nucleus, although the prospect of doing that — maybe I shouldn't be saying this — would be sort of interesting. (Pause) Well, we might destroy it. It's really gonna be blasted by particles and if there are any big particles ....

JC: I've got to add to that from a protection standpoint; it's estimated that these particles, even though they're high velocity, will be micron-size particles. The probe'll be designed with a shield in front of it which is designed to take the hits.

LW: I think it'll be extremely exciting, and it will happen within a year after the launch . . .what is it, it's only a few months?

JC: It's only about four months after the launch.

LW: Yeah. So that will be a very interesting first look; then we'll have three years to think about what that means and decide what to do when we get to Tempel 2.

ASTRO: Tempel 2 is three years more flight time?

JC: Uh-huh. Tempel 2 involves a thrusting of the spacecraft over a long period of time. It goes out to about 3 AU and then comes back in for the rendezvous. Once it's at Tempel 2, it will go through an initial phase of observing the nucleus, making a pass in to collect dust, and then as the nucleus gets in close to its perihelion where it has maximum activity, the spacecraft will stand off from the nucleus and observe it while staying out of the hazard zone. After the nucleus starts to go out away from the Sun, the activity level drops off; then the spacecraft will go in and make successively closer passes to the nucleus. It may end up in orbit about the nucleus at about a 10 km altitude where it will complete more detailed studies of the nucleus itself.

LW: We scientists have something in mind that we would like to do at the end of the nominal mission. The idea is that we'd get closer and closer and closer if everything is OK.

ASTRO: A kamikaze flyby?

LW: Yeah. In the end maybe we'd touch the comet and get some idea about the mechanical strength or nature of the comet nucleus. See, if there are ever going to be any follow-on missions, like collecting samples or boring holes in the comets, you've got to know something about the mechanical nature of the nucleus. If we're going to end the mission anyway, why don't we go up and end it with a good-bye kiss?

ASTRO: In Tempel 2 it seems you'll accomplish your studies of all three components of the comet in great detail. You'd be orbiting in the nucleus very closely. You'd get a look at a relatively inactive comet's nucleus or in a coma ....

LW: Not quite. From the ground we don't observe tail phenomena at Tempel 2, but we may find out that there is some when we get there. Even the coma is weak. The Tempel 2 part of the mission really is nucleus-oriented, that is, it'll answer questions like: Are there little fountains on the surface or, you know, pieces coming off? That's important if we're ever going to understand how tails are formed, but it's not as good as zipping through a big comet tail and seeing what those kinks are.

ASTRO: Why do you expect fountains or something more complex than simple uniform evaporation all over the surfaces?

LW: We've seen comets breaking up. Comet West broke up into four big chunks and I think one or two smaller chunks. I don't remember what the final verdict on that was, but we expect lots of activity.

You also get streamers and forward cones coming out of the nucleus. Where the Sun is incident there's preferential evaporation, so it's going to be very exciting. It's not going to be something dull like evaporating ice cubes.

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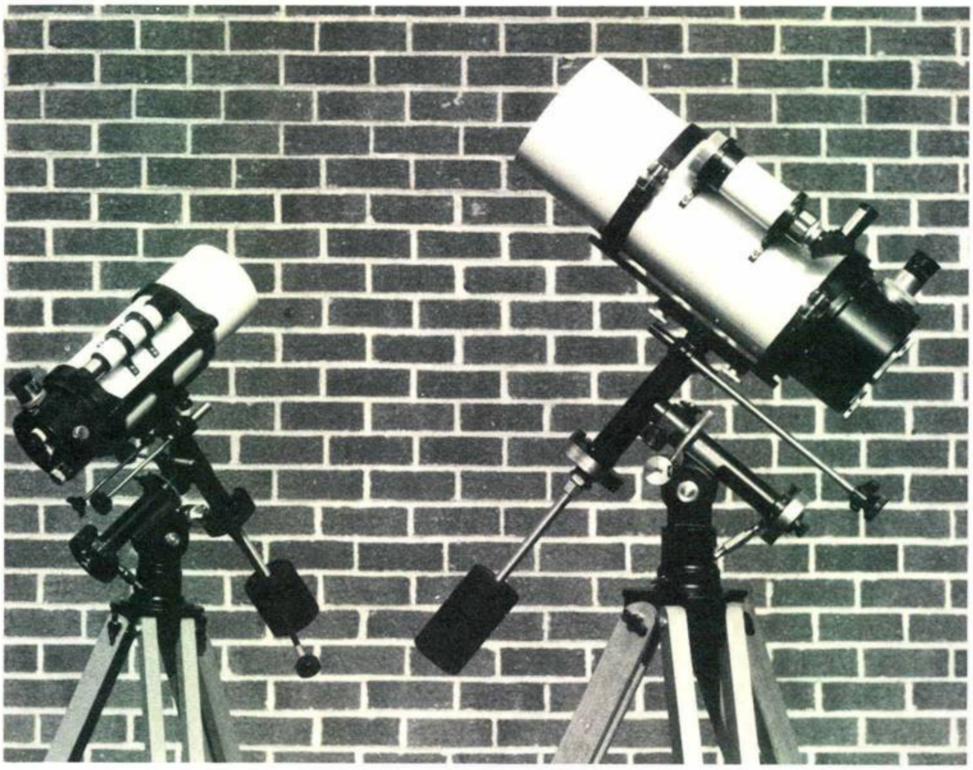

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sky
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jupiter & mars: a double opposition

Ironically, the worst months of 1980 from a weather and comfort standpoint are the ones with the most interesting celestial events. February's double opposition of Jupiter and Mars starts things off, Saturn is well-placed (at opposition next month), and Mercury and Venus are both beautifully paired in the evening sky.

Mercury and Venus

Slipping back into view, Mercury can be found during all of February low in the western sky after sunset. On page 34 there's a diagram showing Mercury's path 45 minutes after sundown.

The planet's greatest eastern elongation (maximum angular separation from the Sun) comes on the 19th, at which time it will be 7½° above the horizon, about 10° south of due west; its brightness will be -0.1 magnitude.

With a telescope, you can watch the planet's disk nearly double its apparent size: from 5 seconds of arc on the 1st to 9.5 on the 29th (1980's a leap year, remember!). This is one of the three best appearances Mercury will make this year, so if you've been hankering to glimpse it....

During February evenings, you'll be treated to a curious sight: bright Venus will "pace" Mercury, that is, move northward along the horizon at about the same rate. Venus will stay about 20° to 30° to the upper left of Mercury and this means any 35 mm camera with a "normal" lens can fit both planets into the frame. Try for a series showing the motion of the pair relative to some foreground object.

By February Venus has become the brightest object in the sky, apart from the Sun and Moon. Venus' magnitude is -3.6, and through a telescope its featureless disk is a dazzling and impressive sight not easily forgotten.

Moon

On the 2nd-4th of February, the Moon will pass through Leo close by Regulus, Jupiter, Mars, and Saturn. Each night the Moon will edge eastward, making conjunctions with each of these objects. Since the Moon's closest approach will come during daylight for some of the objects, you won't get a really close conjunction each time.

Mars

One of two "star" attractions this month, Mars arrives at opposition at 1 a.m. EST on the 25th. A day later, it will be at its closest approach to Earth. (The time difference between opposition and closest approach happens because the paths of the two planets aren't precisely parallel.) Last month's Gazer's Gazette was all about observing Mars with a telescope; let's see now what the naked eye can discern.

Mars' most apparent quality is the distinctive orange or ochre color it possesses, making it look almost like a red-giant star. In fact, Antares, one such star, got its name (meaning "rival of Ares") from just this coincidence.

The next most visible feature is the planet's rapid motion against the background stars; only seldom-seen Mercury moves faster. Watch carefully; over a week to ten days, Mars' position changes will be very noticeable. These rapid movements and the distinctive color (the strongest among all the planets) helped to give Mars a special place in the skylore of many early peoples.

Mars' last naked-eye aspect takes a long time to establish, true though it is. Because Mars circles the Sun in quite an eccentric orbit, its distance both from Earth and the Sun varies constantly, with the result that its apparent brightness will also vary. Over the 15+-year-long cycle of oppositions, Mars' magnitude ranges from -1.0 (at this year's unfavorable and distant opposition) to -2.8 (at a close or favorable one).

Naturally, you can't see this for yourself in a single year or even two. You'll have to keep watching and noting the planet's apparent brightness (as compared with nearby stars) over several years. If you're looking for an easy, ongoing sky watching project that'll make virtually no demands on

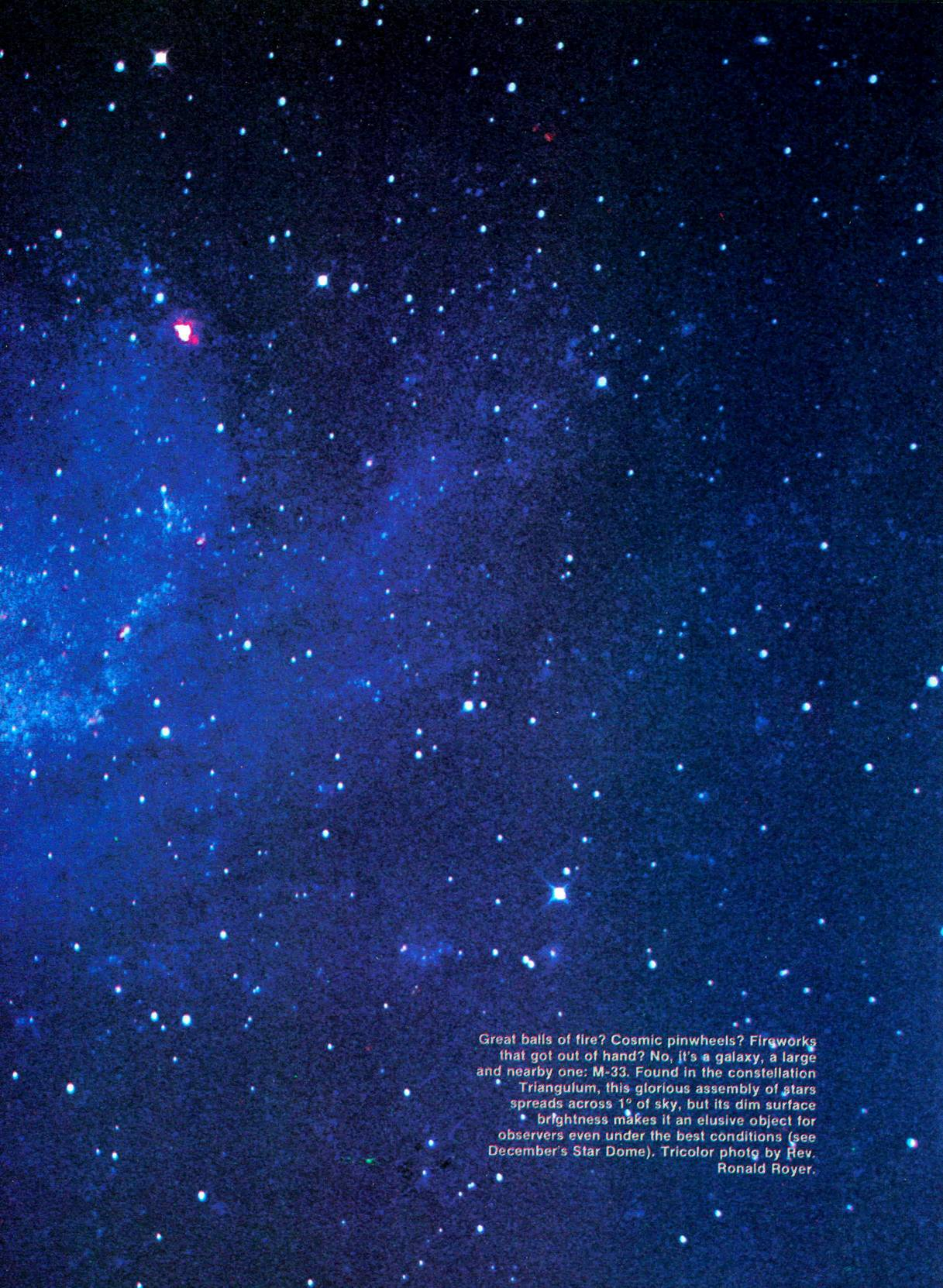
march previews

1	Full moon; penumbral eclipse; Mars-Moon conjunction
2	Mars 3° north of Jupiter
6	Mercury at inferior conjunction
9	Last quarter moon
13	Saturn at opposition
15	Mercury 3° north of Moon
16	New moon
20	Equinox; start of spring
21	Occultation of Aldebaran
23	First quarter
24	Venus at perihelion
31	Full moon

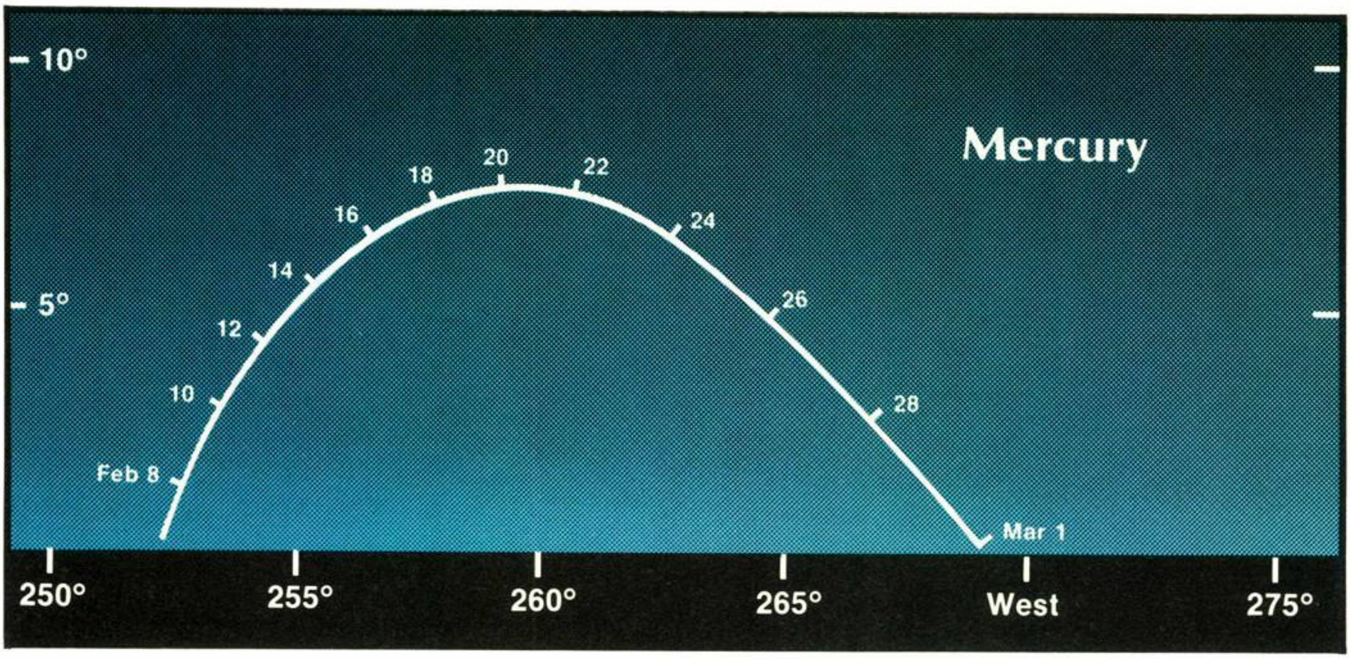
Saturn's opposition brings to a close the quick-paced spate of bright planetary oppositions. Though Pluto, Uranus, and Neptune come to opposition in April, May, and June, respectively, their oppositions can hardly be put in the same class as those of Mars, Jupiter, and Saturn!

Aldebaran's occultation on the 21st will be seen only in the southeastern U.S., with the remainder of the continent seeing a conjunction.

Nine days past new moon, it is early morning on the great plains of the Moon's western hemisphere. Along the line between day and night, hills, valleys, and craters (such as Copernicus, bottom center), struck by the grazing light, display their myriad shapes. Photo by Jacques Guertin.

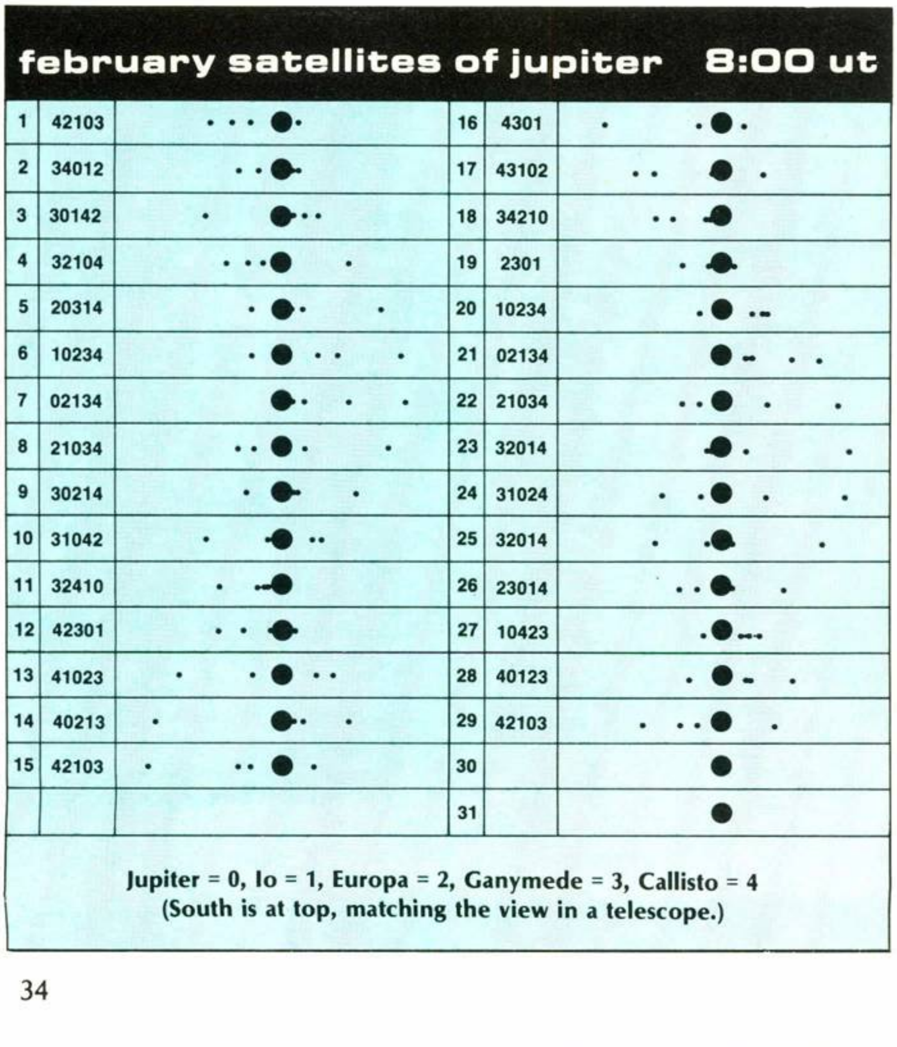


Great balls of fire? Cosmic pinwheels? Fireworks that got out of hand? No, it's a galaxy, a large and nearby one: M-33. Found in the constellation Triangulum, this glorious assembly of stars spreads across 1° of sky, but its dim surface brightness makes it an elusive object for observers even under the best conditions (see December's Star Dome). Tricolor photo by Rev. Ronald Royer.



Three-quarters of an hour after the Sun goes down, Mercury will be visible to the lower right of Venus in the western sky. The diagram above shows its path from early February until the beginning of March. Forty-five minutes after sunset is really a compromise: it's late enough to give a dark sky, yet not so late as to place Mercury impossibly low.

february satellites of jupiter 8:00 ut



1	42103
2	34012
3	30142
4	32104
5	20314
6	10234
7	02134
8	21034
9	30214
10	31042
11	32410
12	42301
13	41023
14	40213
15	42103
16	4301
17	43102
18	34210
19	2301
20	10234
21	02134
22	21034
23	32014
24	31024
25	32014
26	23014
27	10423
28	40123
29	42103
30	
31	

**Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope.)**

your time, try observing Mars' changes throughout one opposition cycle.

Jupiter

The "co-feature" on the planetary program this month is Jupiter. Its opposition comes at 1 p.m. EST on February 24th, just 12 hours before Mars'. At this point, Jupiter's equatorial diameter will extend a fat 44.7 seconds of arc, its broad, delicately-hued disk glowing at -2.1 magnitude.

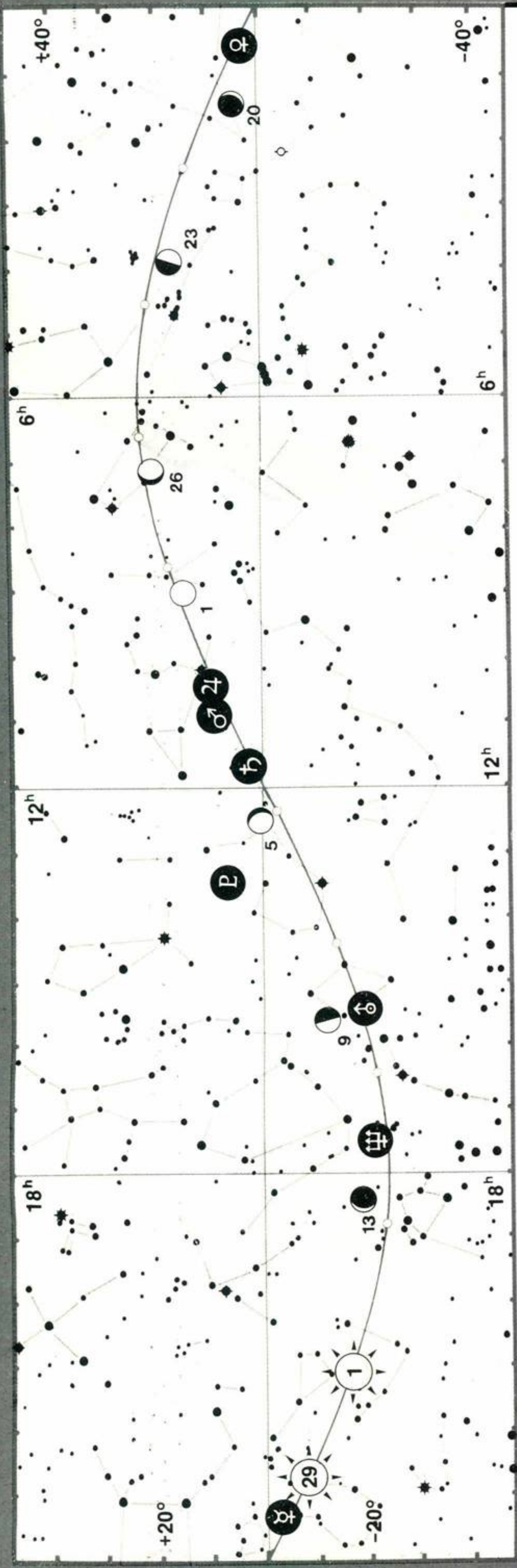
This month is "prime time" for all Jupiter-watchers: get in all the observing you can now. The nights are long (cold, too, but what's mere comfort?) and the wonders Jupiter displays are at their best.

Wander out with your telescope, set it up and, as you peer into that weird and wonderful system out there, let your imagination take a journey. Gaze at the belts, visualizing the storms and racing clouds as the giant planet whirls. Look for the famous Great Red Spot; it will probably look grey or pinkish-grey to you. The GRS seems to have faded somewhat over the past few decades and, you guessed it, nobody knows why. Jupiter's 10 hour spin and internal heat source combine to create a fascinating, always-changing sight.

But while your attention is caught by the planet, don't overlook Jupiter's moons, either. Check in at Gazer's Gazette this month to find out all about what to look for among these little worlds.

Saturn

Saturn is about a month from its opposition, and so is almost as well presented for view as it will be this year. At midmonth, its equatorial diameter will be less than half Jupiter's: only 19.5 arc-seconds. At +0.9 magnitude, it is distinctly a dimmish object for a naked-eye planet, though certainly not hard to find. If you haven't been following the planet's progress over the last few months, a moment's comparison between the sky and this month's Star Dome map will quickly point out the intruder in


+40°
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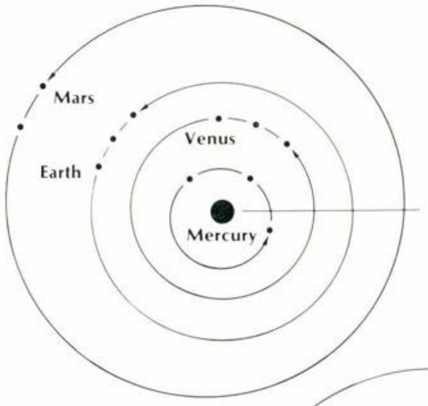
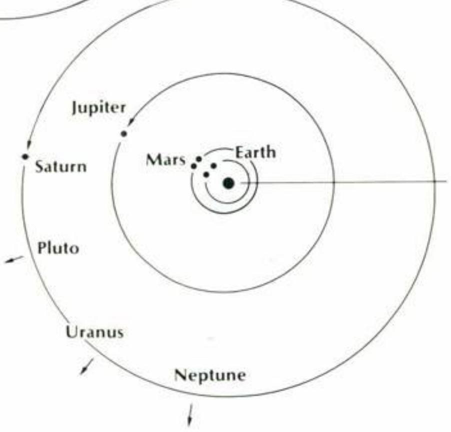
The Planets in Their Courses


Mars
Venus
Earth
Mercury

The positions of Mercury, Venus, Earth, and Mars in their orbits are shown for the beginning, middle, and end of the month. (Mars for the beginning and end only.) The vernal equinox is the line at right.

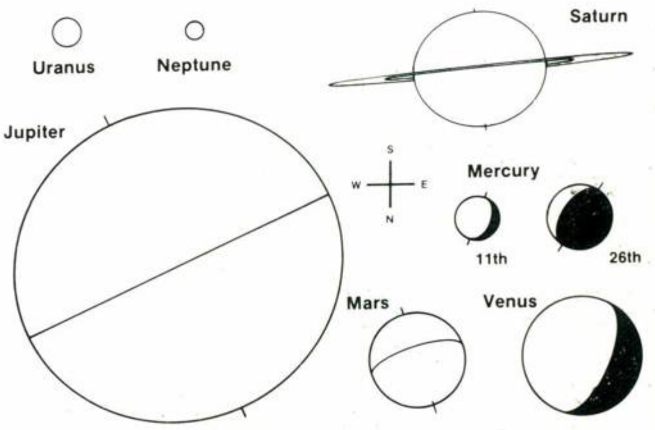
The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter and Saturn for midmonth. The outermost planets' directions are indicated.

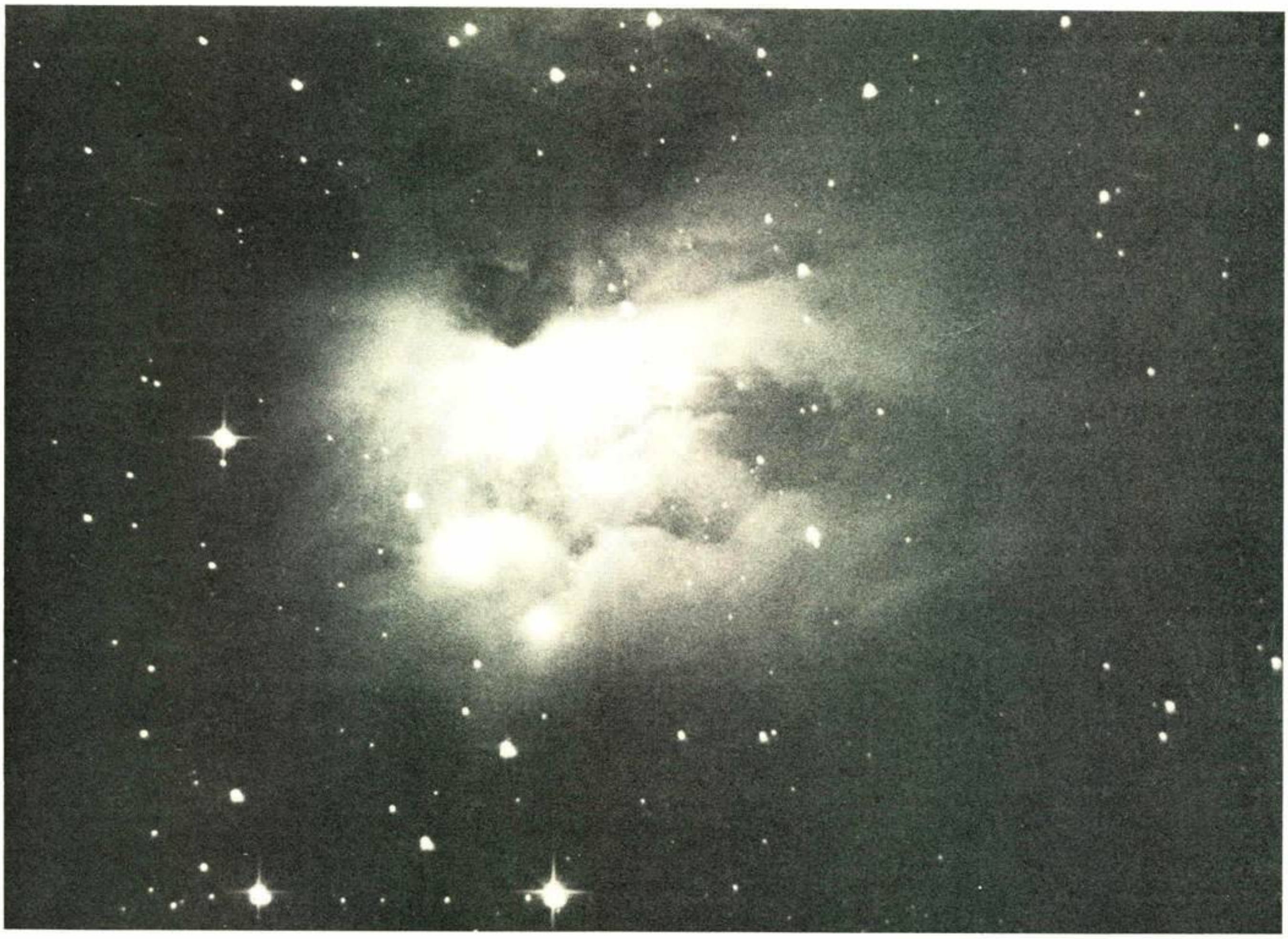

Jupiter
Saturn
Mars
Earth
Pluto
Uranus
Neptune

Positional Data

Planet	Date	R.A. (1980.2)	Dec.	Mag.	Distance (AU) from	
					Earth	Sun
Mercury	☿ 9	$22^h20.9^m$	−11°25.3′	−0.9	1.20	0.34
	19	$23^h12.7^m$	-3°57.9′	-0.2	0.95	0.31
	29	$23^h21.0^m$	-0°35.3′	+1.0	0.70	0.33
Venus	♀ 9	$23^h56.7^m$	-1°04.1′	−3.6	1.12	0.72
	29	$1^h21.4^m$	9°15.6′	−3.6	0.99	0.72
Mars	♂ 15	$10^h51.7^m$	11°58.1′	−0.9	0.69	1.67
Jupiter	♃ 15	$10^h35.2^m$	10°18.4′	−2.1	4.42	5.39
Saturn	♄ 15	$11^h48.0^m$	3°51.7′	+1.0	8.57	9.43
Uranus	⛢ 15	$15^h32.8^m$	−18°51.3′	6.9	18.71	18.73
Neptune	♆ 15	$17^h26.7^m$	−21°51.5′	7.9	30.71	30.28
Pluto	♇ 15	$13^h44.5^m$	7°55.4′	14.0	29.63	30.17

Telescope View


Uranus
Neptune
Saturn
Jupiter
S
W
E
N
Mercury
11th
26th
Mars
Venus



Commonly overlooked by eager telescopists who skate past it on the way to the Orion Nebula (M-42), little NGC-1977 is a dimmer nebula surrounding a 4th magnitude star, 42 Orionis. Lying half a degree north of the Orion Nebula, it won't easily reveal its details in scopes smaller than 6" aperture. Photo by Lee Coombs.

western Virgo.

The sight that will greet you in the eyepiece of your telescope is an oval yellowish-tawny ball with a dark stripe across its middle. The stripe isn't a real marking like the jovian cloud belts; instead, what you're seeing is the rings and their shadow on the ball. The Sun is currently backlighting the rings which are presented to view almost edge-on anyway. The meaning of this is that in small and medium-size telescopes, the rings are invisible, except where they cross the planetary disk.

If the night has good seeing, put on your highest powers and look for belts and spots on the ball. But be warned: you won't find many. Before Pioneer 11, observers partially ascribed Saturn's lackluster appearance (as compared with Jupiter) to its great distance from us, though they also suspected it might really be somewhat less active. Well, the truth will out, and we've now seen that Saturn in general is a "quiet Jupiter" — disappointing perhaps, but this only makes the challenge of hunting for details all the more fun.

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 UT on Jan. 2, then the time in EST would be 10 p.m. Jan. 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m. on March 4.

Uranus

The Sun's seventh planet is in Libra and rises on the 1st of February at about 2:30 a.m. local time. By the end of the month, Uranus-rise will be two hours earlier. During all of February, Uranus will be 2° south of 5.6 magnitude Zeta (ζ) Librae.

Although just within range of naked-eye observation (+5.9), the margin is so slim that some optical aid is necessary. In addition, a telescopic view with powers high enough to make out the 3.7 arc-second disk is virtually required to identify the planet positively.

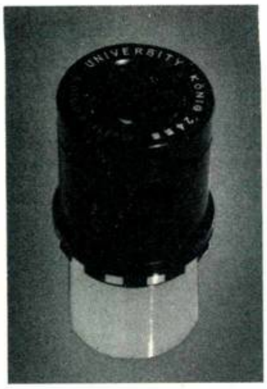
moon data

Full moon: Feb. 1 at 2:21 UT in Cancer. Last quarter: Feb. 9 at 7:35 UT in Libra. New moon: Feb. 16 at 8:51 in Aquarius-Capricornus. First quarter: Feb. 23 at 0:14 UT in Taurus. Apogee: Feb. 5 at 2^h UT; perigee: Feb. 17 at 9^h UT.

Neptune

Farther out and fainter still is Neptune. It lies in western Ophiuchus, an area on the edges of the Milky Way. On February 15th, this region rises around 3 a.m. local time.

About 2° southeast of magnitude 4.5 Xi (ξ) Ophiuchi, the planet has a disk 2.4 seconds of arc in size and of magnitude 7.8. Again, a telescope will be needed in the search; use a low-power, wide-field eyepiece to locate Neptune in relation to Xi, then move in with your higher powers.



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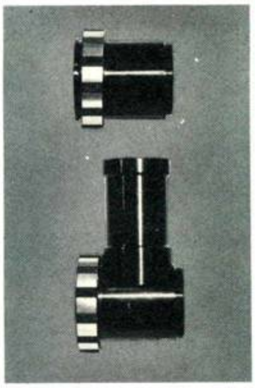

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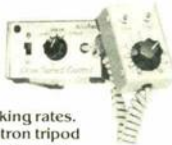

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photographing stellar spectra

photography
in
astronomy

by
Joe Patterson & Patrick Michaud

Have you ever played with a prism and watched the brilliant colors it produces? White sunlight passing through a prism is spread out into a band of colors known as a *spectrum.* You can do the same thing with starlight, and, with your camera and some easily obtainable equipment, you can make your own stellar spectrographs. Getting into astronomical spectroscopy is a lot easier than you might think.

Spectroscopy is one of the most powerful tools of astronomy. Until the advent of modern deep-space probes, the only information earthbound scientists could get about celestial objects came from study of their electromagnetic radiation. In fact, even this, before radio astronomy and orbital observatories expanded the range of wavelengths available, was limited to the visible portion of the spectrum, since Earth's atmosphere blocks most other wavelengths. Yet astronomers gained a great deal of knowledge from the study of this single narrow part of the spectrum.

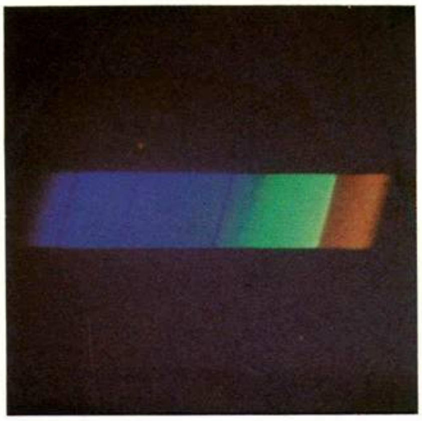
In astronomical spectroscopy, the different wavelengths of visible light from a star or other celestial object are separated into a streak of light called a spectrum. Spectra can be photographed, just like the image of the star itself, and studied at leisure. Dark lines, known as *absorption lines,* and lines brighter than the background continuum — *emission lines* — will appear along the length of the spectrum, and these lines are the "signature" of various elements and compounds. Thus, study of the spectra enables astronomers to determine what the star (or other object) is composed of, as well as other more subtle astrophysical data such as relative abundances, radial motions, and more.

Amateurs can photograph stellar spectra easily with only a modest investment in equipment, yet this area of astronomy has received little attention. Indeed, with the use of modern fast color films, you can easily make photographs which are quite beautiful as well as informative.

Grating or Prism?

Light rays of different wavelengths passing through a prism or diffraction grating are bent, or deviated, by different amounts. The term *deviation* refers to the amount of bending achieved, and is measured as an angle.

Because different wavelengths are bent by different amounts, *dispersion* of the light results — a spreading out of the light into a spectrum. The amount of spreading the light rays undergo (in other words, the overall length of the spectrum) determines the amount of detail and brightness in the spectrum. While a longer spectrum will make the individual absorption and emission lines stand out more strongly, there will be less light at each point, requiring a longer exposure. Obviously then, doubling the dispersion will result in a spectrum only half as bright as the original, so a balance must be struck between the dispersion and brightness on the film.



The spectrum of Sirius, an A1-type star, clearly shows the dark absorption lines of hydrogen. Photographing stellar spectra is an easy project for the amateur astronomer. Photo by David Wirkkala.

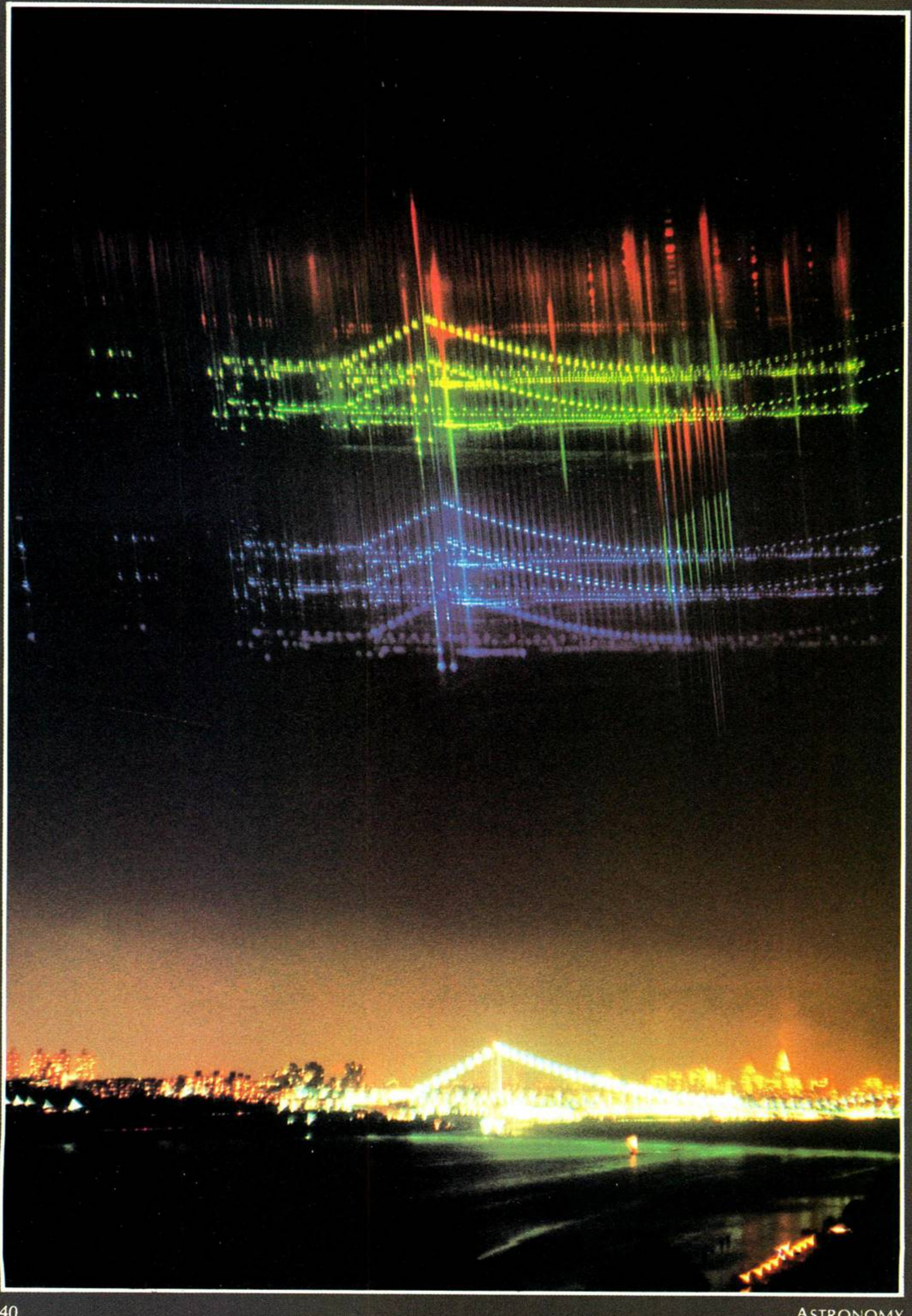
Either a diffraction grating — a thin film on which lines have been etched very close together — or a prism can be used to disperse the light. Replica gratings, which are copies of an original carefully engraved grating, are much cheaper than true diffraction gratings, easily available, and give very good results. You must be very careful when working with gratings, however, as they are very delicate and easily damaged.

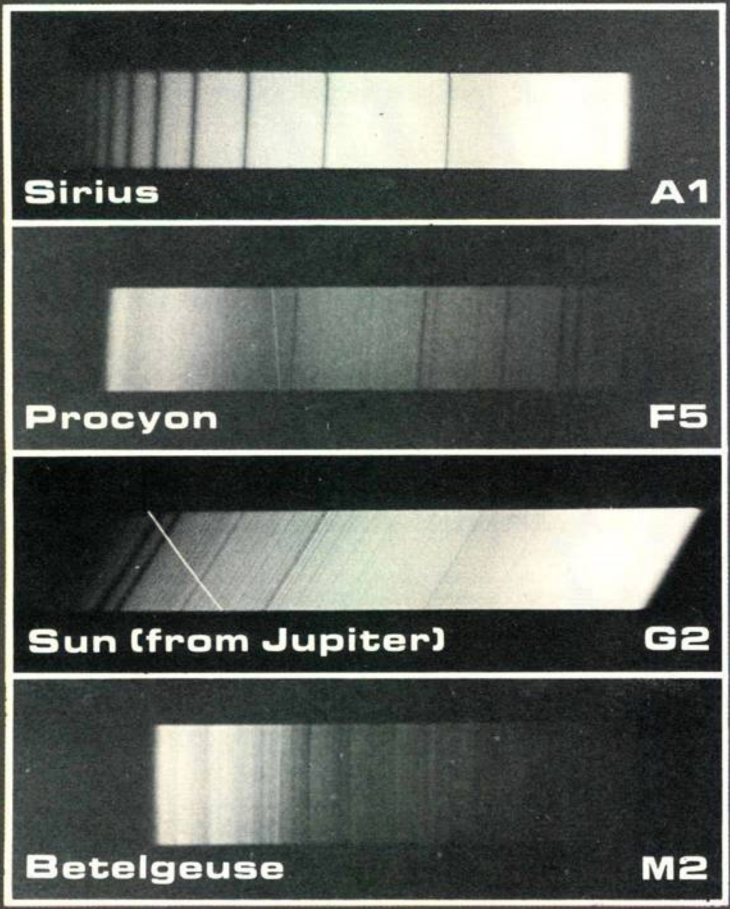
Prisms unfortunately have very little dispersion, which means that unless the focal length is very long, the spectral band will be very short on the focal plane. Thus, if just a camera is used, a long telephoto lens is necessary to obtain a reasonably long spectrum. Sixty-degree equilateral prisms are by far the best — right angle prisms with angles of 45°, 45°, and 90° are only marginally useful.

Prisms are also heavy compared to replica gratings, but they do tend to give brighter images since nearly all the light is diffracted into the spectral band. A good prism transmits about 90% of the incident light, while gratings, depending on quality, range from 40% to 65% efficiency.

Special multiple-element prisms and combination grating-prisms are available which do not deviate the light (but do disperse it), so that the camera can be pointed directly at the star. But these two to five-element prisms result in greater light loss.

Replica gratings, while less expensive and easier to work with, are not as efficient in dispersing light into a spectrum, and a clear white light image will be passed as well as the diffracted spectrum. This can be annoying in a crowded field, but in some cases, it can also enhance the





Opposite: A diffraction grating offers many opportunities for terrestrial photography as well. This photo shows the characteristic colors of the mercury lamps on the George Washington Bridge and the famous red neon glow of downtown New York. Above: The spectra of the three "handle" stars in the Big Dipper — Epsilon (ϵ), Zeta (ζ), and Eta (η) Ursae Majoris — show the characteristic dark lines of hydrogen absorption, indicating that they are A and F-type stars, slightly hotter than the Sun. Photos by Joe Patterson. Left: A "gallery" of spectral types is easy to assemble. The spectrum of the Sun is obtained by photographing the spectrum of the Sun's light reflected from Jupiter. Photos by David Wirkkala.

aesthetic backdrop of the photograph.

Getting Started

Basically, all you need to photograph the spectra of the brighter stars is a 35 mm camera and a prism or diffraction grating to disperse the light — even a telescope is not essential. The basic technique is to carefully tape or mount the grating or prism in front of the camera lens and simply let the stars trail across the field for 5-10 minutes.

Orient the grating or prism so that the direction of the dispersion is north-south. This way the east-west motion of the stars during the exposure will spread the spectral band out into a more easily seen belt instead of a thin line. If you haven't oriented the prism or grating correctly, the spectrum will be more or less askew, with the absorption and emission lines at an angle across the spectrum. If the error is more than about 60°, though, the smearing which will result will wipe out the lines (as well as overlap and blur the colors, if you are using color film).

Don't forget that the orientation of the dispersion must be north-south on the sky, which means that to avoid complicated calculations of angles you must wait till your subject is on the meridian.

Spectroscopy with a Telescope

Adding a telescope will enable the amateur spectroscopist to gather a great deal more light and photograph the spectra of dimmer stars. For the astrophotographer plagued by guiding difficulties, this activity should have special appeal since it not only allows but actually requires guiding error.

Because use of a prism or grating in front of the telescope objective introduces complex alignment and guiding problems, it's much easier to place the prism or grating immediately in front of your camera lens. You will have to construct a special mounting to hold the apparatus at the correct angle to the telescope (see box on page 43 for formula). Again, be sure to orient the prism or grating so that the direction of the dispersion is north-south, so that the spectral line can be deliberately allowed or caused to drift in right ascension (east-west) to widen the spectrum out into a band.

To drift in right ascension, you can use a variable-speed clock drive to great effect. Simply set the speed deliberately faster or slower than sidereal time, and the image of the star will slowly drift in an east-west direction during the exposure. You can also pulse the drive by turning it on and off, but you must have a very good clock drive with no slack or jerkiness resulting from turning it on and off. Very few drives on amateur instruments are this "tight."

Spectral Classes

The spectra of stars are classified according to a traditional system of letters and numbers. Stars fall into one of the seven spectral classes, known in order as O, B, A, F, G, K, and M. (A useful — and well-known — mnemonic for remembering these seven classes in order is the sentence: "**O**h, **B**e **A** **F**ine **G**irl; **K**iss **M**e!")

Each class is further divided into 10 subclasses, labeled with the numbers 0 to 9. Thus a B9 star is very close to an A0 star, but a whole spectral class away from an A9.

The sequence of spectral classes is also a temperature and color sequence. This is because stars have what is known as a *blackbody* or *thermal spectrum*, characterized by a somewhat askew bell-shaped curve representing the amount of radiation emitted at each wavelength. The peak of this curve falls at higher and higher energies (shorter and shorter wavelengths) as the temperature of the star increases. Thus very hot stars emit most of their energy at the blue end of the spectrum or even in the ultraviolet, while cool stars emit mostly red light.

The range of color and temperature is the same as the sequence of spectral classes from O to M. Therefore O-type stars are blue-white and very hot — 50,000 Kelvin or more. B and A stars are cooler and more white in color. F and G move toward the yellow and orange in color, while K and M stars are progressively redder and very cool — 2000 to 3000 K. Our own star the Sun is classified as a G2 type, with a surface temperature of about 6000 K.

The spectral class of stars can be determined from their spectra apart from the color, because each type has a characteristic set of spectral lines. The spectra of O, B, and A stars are marked by absorption lines due to hydrogen — the so-called Balmer series, a regular series of a few strong dark lines. As you move through the classes from O to A, these absorption lines become progressively weaker and less prominent.

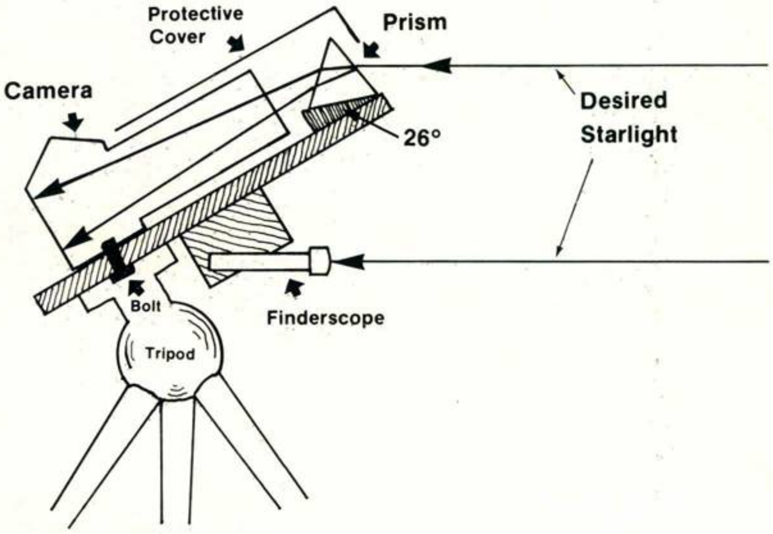
Other elements make a strong appearance in the spectra of F and G stars, resulting in a more complex pattern of lines. The number and complexity of lines reaches its maximum in the spectra of K and M stars.

Spectral Types of Some Brighter Stars

Type	Star	Mag.	R.A. 1980	Dec.
O5	Zeta (ζ) Pup	2.2	$08^h02.9^m$	−39°57′
B0	Epsilon (ε) Ori	1.7	$05^h35.2^m$	−01°13′
B1	Spica	0.9	$13^h24.1^m$	−11°03′
B7	Regulus	1.4	$10^h07.3^m$	+12°04′
B8	Rigel	0.1	$05^h13.6^m$	−08°13′
A0	Vega	0.0	$18^h36.2^m$	+38°46′
A1	Sirius	−1.5	$06^h44.2^m$	−16°42′
A3	Fomalhaut	1.2	$22^h56.5^m$	−29°44′
A7	Altair	0.8	$19^h49.8^m$	+08°49′
F0	Canopus	−0.7	$06^h23.5^m$	−52°41′
F5	Procyon	0.4	$07^h38.2^m$	+05°17′
G2	Sun		*use Jupiter*	
G8	Capella	0.1	$05^h15.2^m$	+45°59′
K0	Dubhe	1.8	$11^h02.5^m$	+61°52′
K2	Arcturus	−0.1	$14^h14.8^m$	+19°17′
K5	Aldebaran	0.9	$04^h34.8^m$	+16°28′
M0	Beta (β) And	2.0	$01^h08.6^m$	+35°31′
M1	Antares	0.9	$16^h28.2^m$	−26°23′
M2	Betelgeuse	0.4	$05^h54.0^m$	+07°24′

Building an Objective Prism Spectrograph

by David Wirkkala



It's easy to construct the simple objective prism spectrograph diagramed here. The camera is a single lens reflex equipped with a 135 mm telephoto lens. The prism is a 60° equilateral extra dense flint 50 mm in length with 50 mm faces and is inclined at an angle of 26° to the mounting board. At this angle, the prism is set at minimum deviation for the starlight to prevent astigmatism of the image.

The angle of minimum deviation is given by the formula:

$$D = [2 \arcsin (n \, \mathrm{Sin} \tfrac{1}{2} A)] - A$$

where $A = 60°$, D = angle of minimum deviation, and $n = 1.66$ for extra dense flint glass. The angle of minimum deviation in this case turns out to be 52°. This means that the starlight is bent at angles of 26° when it enters and exits the prism.

To avoid gluing the prism to the mounting board, a special holder can be constructed. Bend a piece of aluminum so that the prism can slide in and out of the holder, and then glue felt to the aluminum to prevent scratching of the prism.

It's helpful to attach a small 3 to 5x finder to the mounting board to aid in locating the desired star. Attach the entire camera-prism assembly to a camera tripod for use. In order to prevent extraneous light from entering the camera, use a protective cover.

The spectrograph can be adjusted by focusing on a distant street light. Center the street light's spectrum in the camera viewer and then adjust the finder scope so that the light is centered in it.

Using a "Star Finder" or planisphere, determine when the desired star will be on the meridian. Place the spectrograph on level ground and orient it so that the camera is pointing south. When the star is centered in the finder scope, its spectrum will appear as a vertical line in the camera viewfinder. By taking a time exposure, the star will drift from left to right, spreading its spectrum from a thin line into a broad band. If the star is not on the meridian, its spectrum will be slanted, unless the entire apparatus is tilted to the proper angle.

With this simple spectrograph and a little experimentation, you can soon build your own library of stellar spectra.

Alignment

Prisms and gratings achieve dispersion of white light into a spectrum because they refract (bend) light rays of different wavelengths by different amounts. But this means that the original light path's direction is changed, so you can't simply point the camera (or telescope) with an objective prism or grating in the direction of the star or object to be photographed. Instead, you have to aim at an angle. If you use a camera alone (either with or without a telephoto lens), the camera can be mounted on a board along with a small finder scope positioned so that when the star is centered in the finder, its spectrum is in the field of the camera (see box on page 43).

Aiming a telescope with an objective prism or grating is more complicated. The degree of adjustment possible with finder scope mountings in most cases isn't sufficient to allow the finder to be moved to the proper angle. Instead, start with a prism or grating in front of the camera even when using a telescope, instead of attempting objective prism spectroscopy right away.

Film

Either black-and-white or color film can be used to photograph stellar spectra, but in either case use as fast a film as possible. In photographing stellar spectra, you're more interested in gathering light than in definition of detail, so the graininess of fast film isn't a drawback. Tri-X (400 ASA) and Ektachrome 400 color film both produce excellent results, but don't hesitate to experiment with other films.

Black-and-white will show the absorption and emission lines clearly, and is better for actual identification and study of specific features. Color film, though, produces much more beautiful spectra, showing the full range of colors making up the light from the star. With color film it should be clear at a glance that the spectrum of a particularly red star like Betelgeuse is far brighter in the red part of the spectrum than a blue-white star like Sirius. But you may find it more difficult to pick out individual spectral lines on color film.

With a little practice, you'll soon be able to recognize the type of a particular stellar spectrum — at least which main class it falls into — and therefore what its color and temperature are, even on black-and-white film. (See box on page 42.)

An interesting project to begin with is to obtain color spectra of individual stars representing each spectral type from O to M. In no time, you'll be amazed at how much you can tell about a star with a single glance at its spectrum and you'll be well on your way to being an amateur astronomical spectroscopist.

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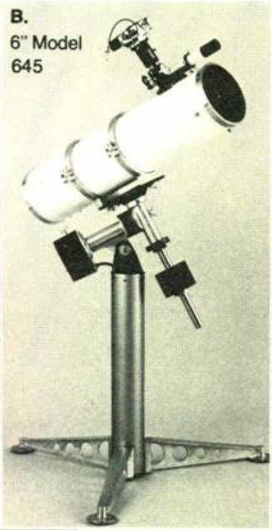
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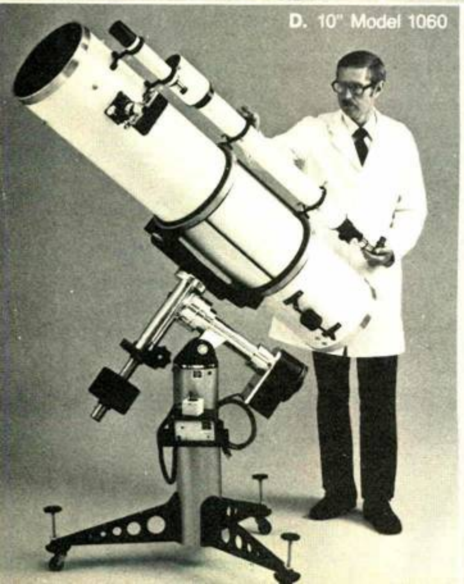
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F.	**MODEL 1266: 12½" f/6** with Motor Drive	**1675.00**

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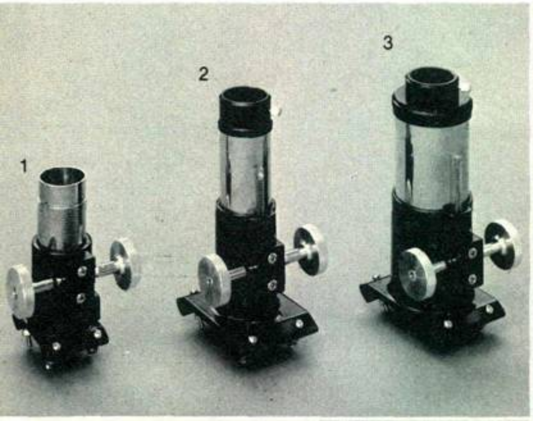

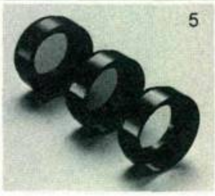

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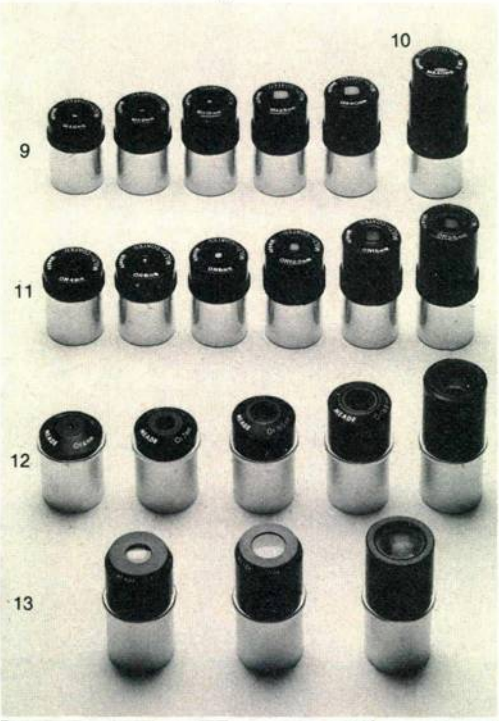

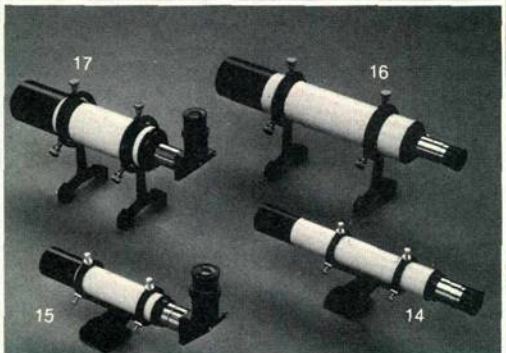

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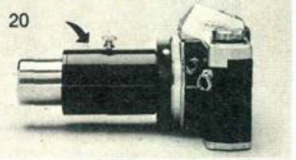

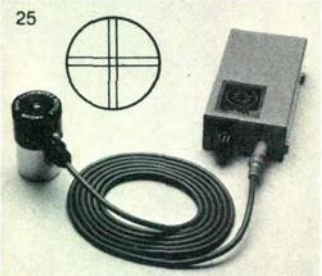

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gazer's
gazette

jupiter's miniature solar system

Three hundred and seventy years ago this month, an extraordinary series of astronomical observations were made. If their subjects were commonplace, the instrumentation was anything but: using the world's first astronomical telescope, Galileo was helping to boot celestial science out of its medieval torpor.

With several low-power, small aperture "optick tubes" (as they were first called in English), Galileo found many things, but few discoveries gave him as much pleasure as his "Medicean stars" — the 4 brightest jovian moons.

To see how they looked to Galileo, take a telescope, or even a pair of binoculars, and direct it on Jupiter. If the powers you use are low (7 to 30x, say), the view you'll have is about what he had. (His most powerful scope had approximately 30x, but its optical quality wasn't very good.)

And what'll you see? First, a bright dot — Jupiter — that seems to overwhelm your eye with its glare. Next, you'll notice up to four pinpoints of light strung along a line through the dot's center, some to the east and some to the west. These pinpoints are Galileo's Medicean stars.

Look for the Pattern

Just for fun, draw a lot of little Jupiters (¼" diameter, say) running in a row down the center of a piece of paper. Then each night take your telescope or binoculars outside and plot the positions of the moonlets you see, leaving a blank Jupiter on cloudy nights. Note the dates and times on the drawing, and try to observe the same time every day.

After a while, you'll begin to see a pattern emerging. There's one little speck of light that always stays close to the planet, shifting from side to side each night. A bit farther away is another little speck that moves almost as fast, and takes a little more than a day to change sides. Next out is a moonlet that looks a wee brighter than the others and moves from one side to the other in about 3½ days. Farthest from Jupiter is a point of light that needs fully two weeks to go from east side to west and back again. These four moons, from Jupiter outward, are Io, Europa, Ganymede, and Callisto.

By their behavior in a telescope, you might think they're attached to Jupiter by some sort of giant invisible rubber band: back and forth they go, endlessly. What's actually happening is that we (and Earth) lie almost exactly in the moons' orbital plane, so as they sweep around Jupiter in their circular paths, we get little sense of their real motion in space.

Transits, Eclipses and Occultations

But if you increase the magnification of your telescope, you can begin to gain a sense of what's really happening out there. 100x to 200x will effectively move you closer to the jovian system and reveal phenomena which provide a fascinating view. These phenomena fall into three categories: *transits*, *eclipses*, and *occultations*; some are more easily seen than others, but all are delightful.

Since we are looking at Jupiter almost in the moons' orbital plane, you might expect them to cross over the face of the planet from time to time, and so they do. Such an event (called a transit) has two different aspects. When the satellite itself transits, you'll see a dot of light superimposed on Jupiter's cloud tops. This dot's visibility will vary a great deal, depending on which moon it is: Io looks dusky, Europa is very light and hard to see, Ganymede appears dark and easy to pick out, and Callisto also looks dark.

Even hard-to-locate satellites can be found easily at the times when they are entering or leaving the disk, since Jupiter's edge (or limb) is darker than the rest of the planet. The moon then stands out clearly though it may be lost on the disk proper.

The other type of transit is when the shadow of a moon crosses the disk. These are very easy to notice since no matter where on the disk it falls, there's no mistaking that black dot. Sometimes you'll even see two or more shadows in transit at once, though more than two is rare.

Before opposition (this year: February 24th), you'll see the shadow enter onto Jupiter's disk ahead of the satellite; after opposition, the satellite goes first. The time elapsing between satellite and shadow ingresses can be as long as several hours in the case of the outer slow-moving moons.

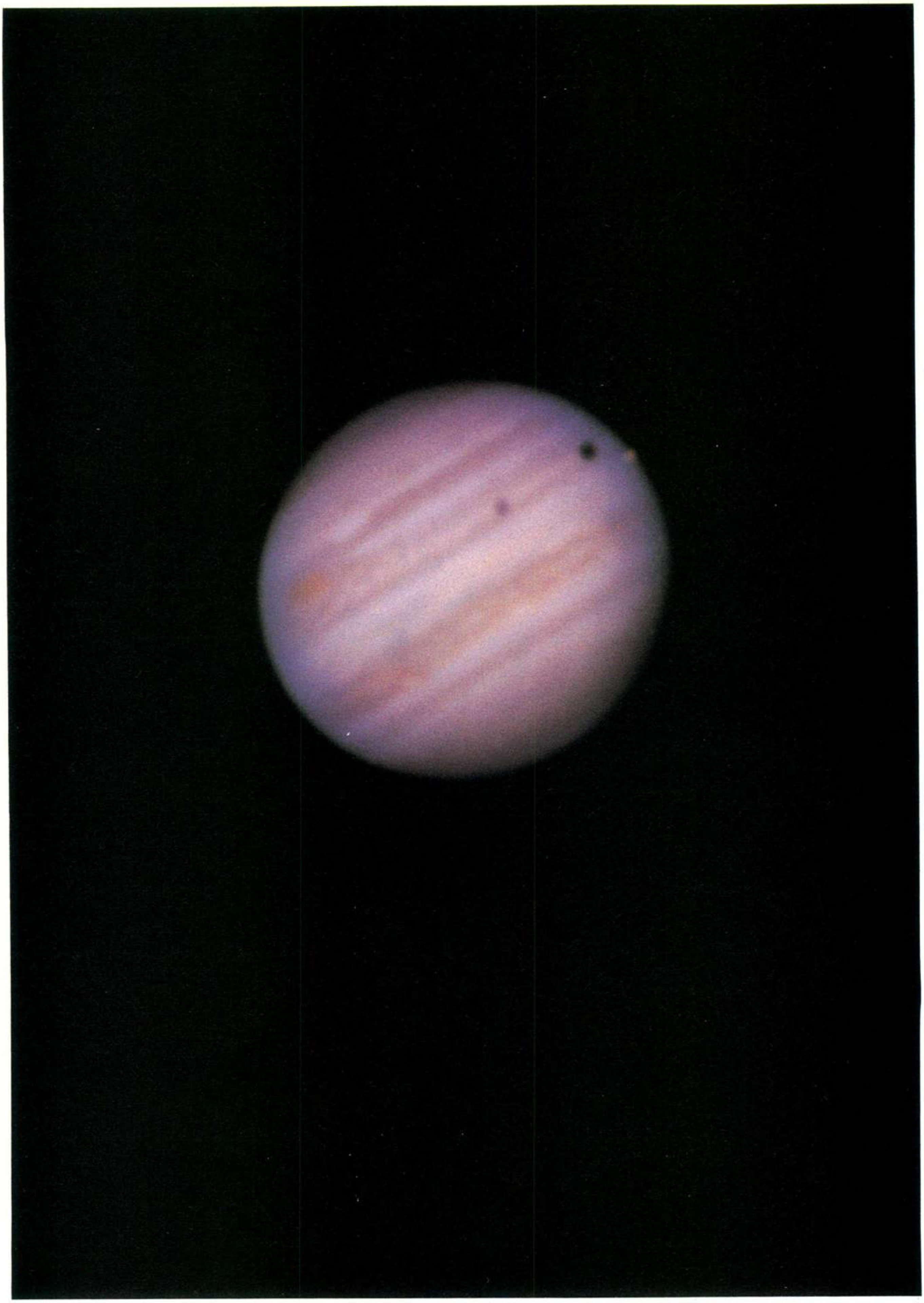
When Jupiter is a month or more on either side of the time of opposition, you can often see a shadow lying on the planet cast by a satellite well off the disk. This strong 3-dimensional effect is very impressive and it's easy to imagine really being there.

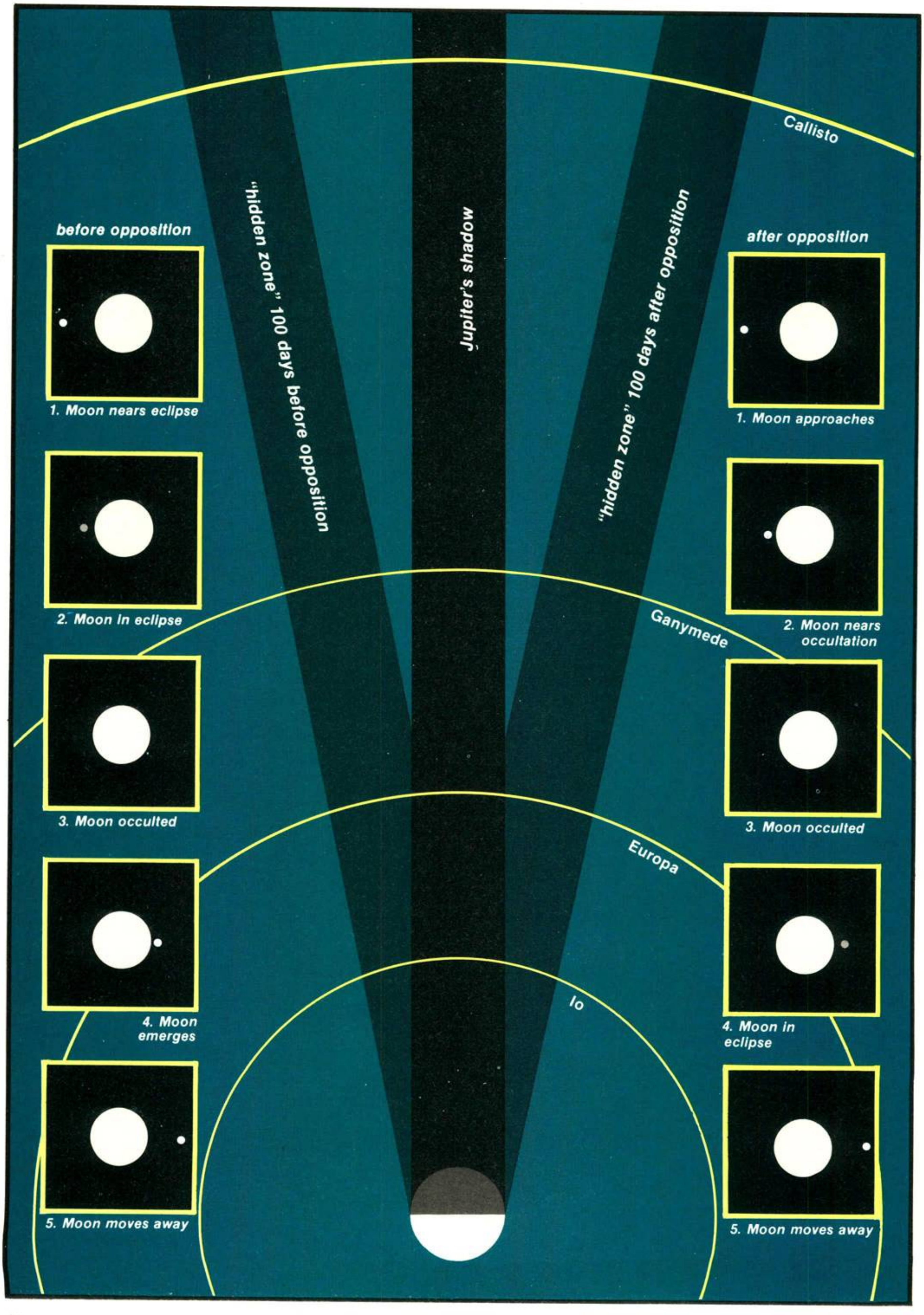
Scads of Lunar Eclipses

Behind Jupiter is a long cone of shadow stretching out several hundred million kilometers. During part of each orbit, the satellites pass through this shadow, making a (jovian) lunar eclipse. The best time to watch for these isn't around opposition, for then Jupiter's shadow extends directly away from you. Far better are the periods up to about 2 weeks before opposition and starting 2 weeks after. Then the shadow lies slightly to one side or the other of Jupiter and you see the moons going into eclipse (before opposition) or coming out (after).

Eclipse events are especially exciting. Picture it: There you sit,

If you observe Jupiter with a telescope for even a short time, you'll sooner or later spy the shadow of a moon creeping across the ball; here we see two such shadows. At upper right is one moon with its shadow ***close by. In the other case, all we see is the*** **shadow since the moon itself has blended into the belt detail. Photo by Charles Capen.**




Callisto
before opposition
"hidden zone" 100 days before opposition
Jupiter's shadow
"hidden zone" 100 days after opposition
after opposition
1. Moon nears eclipse
1. Moon approaches
2. Moon in eclipse
Ganymede
2. Moon nears occultation
3. Moon occulted
3. Moon occulted
Europa
4. Moon emerges
Io
4. Moon in eclipse
5. Moon moves away
5. Moon moves away

Left: Jupiter and the Galilean moons' orbits are shown in true scale; stretching out straight behind the planet is its long cone of shadow. Jupiter's bulk always hides one part or another of the moons' orbits from our view; shown are the two extremes this hidden zone can extend to (at opposition, of course, the zone lies essentially in line with the shadow). The inset boxes show telescopic views with south at the top. Above: With binoculars or a low power telescope this is how the system looks. From left to right are Callisto, Ganymede, Io, Jupiter, and Europa. Photo by Steve Reed.

staring into the eyepiece when suddenly the moon you're watching begins to fade. It gets dimmer and dimmer until it disappears. And then when you know a moon is going to come out from eclipse, you make a guess (a rough one usually suffices) where the moon will be as it comes out. You sit there, watching. At the proper time, you think you can see the tiniest pinpoint...you aren't quite sure...then there it is!

With the innermost moon, Io, you'll never see both the entry into an eclipse and the exit from the same one; the moon orbits too close to Jupiter. The sequence of events will always have Io disappearing into eclipse and emerging from occultation (before opposition), or occulted by the planet and emerging from eclipse (after opposition). The total elapsed time will be about 2 hours 15 minutes.

In some years (but not 1980), you occasionally see both the beginning and end of Europa's eclipses. Otherwise, the situation is just like Io, but the time interval lasts about 30 minutes longer.

With Ganymede and Callisto, both entry into and exit from eclipse are usually visible, except close to opposition. The eclipse durations vary (because the moons' paths aren't always central through Jupiter's shadow), averaging about 3 hours 15 minutes and 4 hours, respectively.

Moons and the Speed of Light

The eclipses are especially notable because they helped one astronomer make the first-ever determination of the speed of light. Ole Roemer was observing the moons in the late 17th century, when he noticed that near opposition, their eclipses came systematically early (according to predictions), and around conjunction with the Sun they were just as systematically late. A flash of insight showed him that the time difference was due to the light signal from the eclipse having (or not having) to cross the width of Earth's orbit. Knowing roughly the size of our orbit and the time delay involved, he worked out an approximate velocity of light.

A Rare Event

1980 is remarkable for a rare event: all four satellites will be invisible at the same time, providing a "moonless" Jupiter. Io will be in transit; Europa and Ganymede, occulted or in eclipse; and Callisto, in eclipse.

This remarkable state of affairs will last for about two hours, but here's the catch: it happens at around 12:00, Universal Time, on the 9th of April. Noon UT is 7 a.m. EST and 4 a.m. PST, the same day. Since Jupiter sets at about 5 a.m. local standard time, only the observers in the western parts of the continent (and Hawaii) are going to see this. But try anyway, wherever you live, for the next such arrangement won't happen until 1990.

Try Your Naked Eye, Too

If your eyesight is keen, or even if it isn't, you might like to try confirming what has been persistently reported since the invention of the telescope:

Want to Know More?

Getting started observing the Galilean moons is absurdly easy: take your scope or binocs outside and look up. On the other hand, you may want to hunt out all the phenomena systematically, knowing in advance when such and such an event is to take place.

On page 50 there's a table which lists a number of events for 1980 with their dates and times. The list isn't complete, for we don't have space for a detailed tabulation. The standard source for all jovian satellite events (and much other astronomical data) is the *American Ephemeris and Nautical Almanac*, published each year jointly by the U.S. Naval Observatory and the Royal Greenwich Observatory.

The current year's edition is available in most public libraries (if they don't have it, tell them they ought to), or can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20504. The 1980 volume costs $11.25. The GPO also has bookstores in several large cities; check your phone book.

The Jovian Moons' Events

This table lists a number of upcoming events for the jovian moons. It isn't complete as it covers only those events visible at once from all four time zones of the continental U.S. The first two columns give the date and time in Universal Time; the third names the moon involved. The last column describes the event.

The decreasing number of events as spring progresses reflects Jupiter's proximity to the Sun; the elapsed time between sunset and Jupiter-set becomes shorter and shorter.

Date	Time (UT)	Moon	Event
Feb. 1	10:46	Io	eclipse disap.
	12:44	Ganymede	shadow begin
2	1:48	Europa	eclipse disap.
	8:06	Io	shadow begin
3	5:14	Io	eclipse disap.
4	4:51	Io	shadow end
	5:19	Io	transit begin
	8:08	Ganymede	occultation reapp.
7	9:19	Europa	shadow begin
	10:10	Europa	transit begin
9	7:56	Europa	occultation reapp.
	10:00	Io	shadow begin
	10:22	Io	transit begin
10	7:08	Io	eclipse disap.
	9:47	Io	occultation reapp.
11	4:28	Io	shadow begin
	4:48	Io	transit begin
12	6:43	Ganymede	eclipse disap.
16	6:56	Europa	eclipse disap.
	10:10	Europa	occultation reapp.
17	9:02	Io	eclipse disap.
18	6:22	Io	shadow begin
	6:31	Io	transit begin
19	5:32	Callisto	eclipse disap.
	5:57	Io	occultation reapp.
23	9:30	Europa	eclipse disap.
25	6:42	Europa	transit end
	6:44	Europa	shadow end
	8:15	Io	transit begin
	8:15	Io	shadow begin
26	7:43	Io	eclipse reapp.
27	5:00	Io	shadow begin
Mar. 1	4:06	Ganymede	transit begin
	4:37	Ganymede	shadow begin
	7:33	Ganymede	transit end
	8:09	Ganymede	shadow end
3	6:03	Europa	transit begin
	6:25	Europa	shadow begin
4	9:38	Io	eclipse reapp.
5	4:11	Europa	eclipse reapp.
	4:24	Io	transit begin
	4:38	Io	shadow begin
6	4:06	Io	eclipse reapp.
7	3:47	Callisto	eclipse reapp.
8	7:22	Ganymede	transit begin
	8:35	Ganymede	shadow begin
10	8:19	Europa	transit begin
	9:02	Europa	shadow begin
11	8:52	Io	occultation disap.
12	6:08	Io	transit begin
	6:32	Io	shadow begin
	6:45	Europa	eclipse reapp.
13	6:01	Io	eclipse reapp.
15	4:23	Callisto	transit begin
	8:39	Callisto	shadow begin
19	5:24	Europa	occultation disap.
	6:08	Ganymede	eclipse reapp.
	7:53	Io	transit begin
	8:26	Io	shadow begin
	9:19	Europa	eclipse reapp.
20	7:56	Io	eclipse disap.
28	3:35	Europa	shadow begin
	4:05	Io	transit begin
	4:49	Io	shadow begin
29	4:19	Io	eclipse reapp.
Apr. 4	4:27	Europa	transit begin
	5:52	Io	transit begin
	6:12	Europa	shadow begin
	6:43	Io	shadow begin
5	6:14	Io	eclipse reapp.
6	3:44	Europa	eclipse reapp.
9	6:42	Callisto	occultation reapp.
11	6:50	Europa	transit begin
13	4:30	Ganymede	shadow begin
20	3:57	Io	transit begin
	4:03	Ganymede	transit begin
	5:01	Io	shadow begin
21	4:34	Io	eclipse reapp.
26	5:45	Callisto	eclipse disap.
27	5:47	Io	transit begin
	6:56	Io	shadow begin
28	6:29	Io	eclipse reapp.
May 5	4:52	Io	occultation disap.
13	5:13	Io	shadow begin
14	4:48	Io	eclipse reapp.
26	4:25	Ganymede	shadow begin

namely seeing the moons with the naked eye.

If it can be done, it's certainly no easy task, for there are several physical difficulties stacked against you. It isn't that the moons are dim; in fact, all four would be apparent to the naked eye in a dark sky. The big problem is Jupiter's glare. You'll need very sharp vision indeed to detect those little points of light only a few arc-seconds away from bright Jupiter. After all, the brightness difference is 7 or 8 magnitudes.

You'll do best around sunset or sunrise when the sky has some light in it to reduce the blaze of Jupiter. The timing will be tricky because if you're too early, the moons will be washed out, and if you're too late, the glare overpowers them. Another method is to block the glare of Jupiter with an object (tree limb, edge of a building, etc.) at some distance. Haze and turbulence — any sort of atmospheric disturbance — will also lessen your chances, but good luck anyway. (We'd be interested in hearing what results you have, but be sure you don't prejudice the attempt by looking first through binoculars or a telescope.)

Watching these four moons scuttle back and forth as they mimic the Sun's family in miniature has been one of astronomy's continuing attractions for more than three and a half centuries, and there are few others as accessible. It doesn't seem to matter much how often you see them — they still fascinate as much on the 1000th look as on the first. Maybe even more, as by then they've become old friends.

— Robert Burnham

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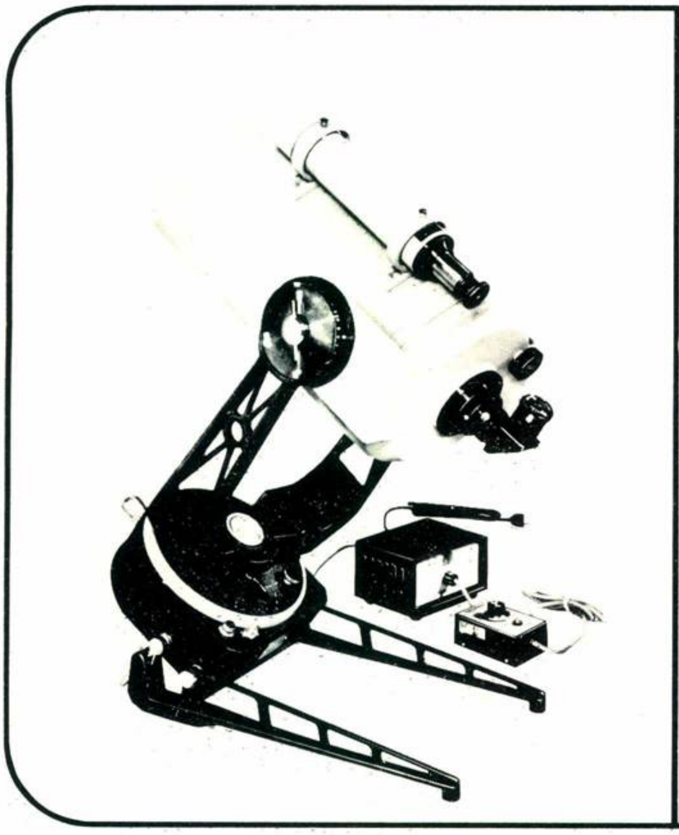

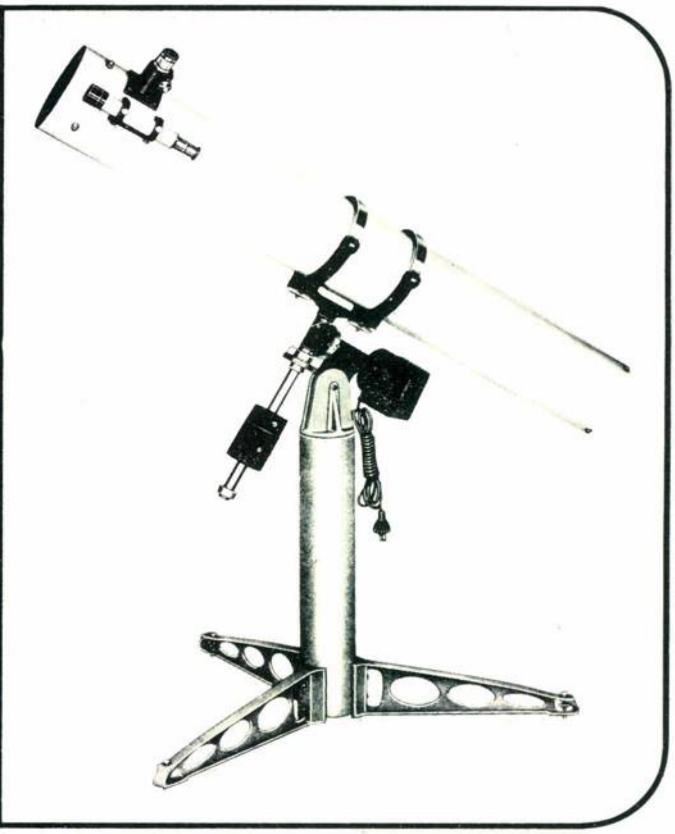

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cool your telescope

equipment atlas

Have you ever carried your telescope outside on a cold crisp night, eagerly uncapped the tube, inserted an eyepiece, and prepared to study the fine details of the martian polar cap or belt details on Jupiter...only to see nothing but a blurry mass of swirling light? Have you, perhaps anxiously, wondered what could have gone wrong with your telescope, and then a few hours later, when the images began coming through clear and crisp, wondered what happened?

Telescopes don't do their best when they're warmer than the surrounding air. It is, in fact, a good idea to always give any fine optical instrument an hour or more to accommodate to any large temperature change.

Why? There are a number of reasons. Warm air flowing inside the tube can distort the images. The optical parts, accurate to millionths of an inch, may become distorted as they cool, temporarily destroying performance. Finally, dew or frost forming on lenses or eyepieces can block light.

The solution? Cool your telescope before you begin to observe.

Turbulence in the Tube

Newtonian reflectors are particularly affected. They are open at the top end and usually partly open around the mirror at the bottom end. The path of the light inside the telescope must pass through the column of air inside the tube twice on its way to the eyepiece: once down the tube to the mirror and once back up to the eyepiece.

Imagine what it's like inside the tube when you first carry it outdoors from a comfortably heated 68° house to the middle of the backyard on a night around 25°. As you uncap the tube, and perhaps eagerly prepare to observe, the hot air in the tube begins to convect upward (hot air really does rise) while cold air begins to flow in from the bottom. Warm and cold air swirl together in eddylike patterns.

The problem is that warm and cold air don't transmit light exactly the same way (because, in optical jargon, their refractive indices are not the same) and the light, passing through the mixing warm and cold air, is bent at every interface. By the time it's traversed six to ten feet of turbulent air, the light beam is pretty badly messed up.

Within a few minutes, most of the warm air originally inside the tube will have flowed out. However, the tube itself is still warm and so are the diagonal and primary mirror. The air next to their surfaces is heated and flows off in slow lazy curls. If you could see it, it would resemble smoke.

After twenty minutes or so, the secondary mirror and the tube, if it's made of a phenolic or fibrous material such as spiral-wound paper, will have cooled, leaving the primary mirror the warmest object in the telescope. By this time, however, the telescope ought to be giving pretty good images.

Since the mirror can't cool uniformly, but cools from the outside in, it undergoes temporary distortion while cooling. While not severe, it does prevent the mirror from giving its very best performance. In a 6" telescope, the mirror will cool within an hour if the tube is well ventilated; in a 10", within two hours. Once the mirror has fully cooled, the telescope will give its very best performance.

Thus, when you take a medium-size Newtonian outside to observe when it's cold, you'll see extremely bad performance for several minutes, followed by slowly improving performance for an hour, followed by top performance.

Closed Tube Telescopes

Refractor and catadioptric telescopes have closed tubes, and although cooling them is just as important as cooling a Newtonian, they behave quite differently while cooling.

Because the tube is closed, there is no period of extremely rough turbulence. Warm air clinging to and around the outside of the tube is dispersed in a fraction of a minute, so the telescope gives good performance as soon as it's set up because there is no internal mixing.

But as the tube and front lens begin to cool, the air inside cools by conduction and begins to convect slowly around the interior of the telescope. Performance degrades somewhat, perhaps surprising an observer who had seen better images during the first five or ten minutes. If the air inside the tube is moist, dew may form on the *inside* of the cooling tube or corrector lens.

Warm air plumes may rise off the secondary mirror housing in catadioptrics for an hour or so. The primary mirror, effectively insulated inside the tube, can take hours to fully cool and be capable of giving you best performance.

In refractors, air warmed by the objective tends to be quickly dispersed into the surrounding air, while convection inside the tube proceeds slowly because of the long thin tube. The objective of a refractor

GREG KOT.

is not as temperature-sensitive as a mirror, and it cools quickly because it's in direct contact with cold air.

Refractors, of all the different kinds of telescopes, are least affected by being taken outside on a cold night. If your first telescope was a small refractor, and your second a medium-sized Newtonian reflector, the need for a cool-down period might come as a real shock.

Seeing the Moving Air

If all this dynamic air flow inside a telescope sounds suspiciously like the 11-o'clock weather report, and slightly unreal, you can see it for yourself. Point your telescope at a bright star, put in a medium-power eyepiece, and throw the image out of focus. You should see a disk of light with the secondary, spider, mirror clips, and other obstructions in the light path silhouetted on it. Notice that the disk is not uniform: there are shadowy forms moving around slowly as well as a fast wavelike shimmy crossing the mirror. The shadow forms are blobs of air in the telescope; the fast wavy motion is turbulence outside the telescope, the cause of "seeing."

Take off your gloves and put your hand into the light path from the underside of the tube. What do you see? Your fingers, in silhouette (wiggle them to make sure!), and rising from them, a *plume of warm air*. Try blowing across the front of the telescope or lighting a match and watching the hot air from it.

Observer Turbulence

During an observing session, of course, you don't want warm air from your hands, face, or body to flow into the path of light, but there isn't too much you can do about it.

If there's a light breeze blowing, you'll have less trouble from body heat if you are downwind of the telescope. You can attach a lightweight tube made of file-folder cardboard or posterboard to deflect rising warm air from your body and, of course, you should take care not to breathe toward the end of the tube if you're trying to observe features on Mars. For low-power observing, such as finding deep-sky objects, turbulence usually doesn't matter.

Avoiding Dew

Dew, or frost in colder climates, is condensation of water vapor in the air on cold surfaces. Dew doesn't form anyplace it pleases though; it forms only on surfaces that are *colder* than the surrounding air. If the humidity is high, dew forms on surfaces just a little colder than the air temperature, while if the humidity is low, dew can only form on *much* colder surfaces.

It's not immediately obvious why anything should get colder than the surrounding air. The culprit turns out to be infrared (heat) radiation. A telescope sitting in a room radiates to the walls of the room and the walls of the room radiate equally back to it. A telescope exposed to the night sky, which is very cold, radiates as before, but receives little radiation (heat) in return. The air cannot warm it quickly enough, so it becomes colder than the air and dews up.

The corrector lens of a catadioptric is fully exposed to the sky and thus can cool and dew up. The mirror of a Newtonian is exposed mainly to the inside of the telescope tube, which is close to air temperature; hence Newtonian primaries hardly ever dew up. Adding a dewcap protects the catadioptric's lens from dew partly by reducing radiation to the sky.

One very effective way to remove dew (if you've got electricity at your observing site) is to shine a 150-watt spotlamp on surfaces that are prone to dewing. The infrared from the lamp heats cold surfaces very effectively without heating the air in the tube or the mirrors. Another way is to blow air from a hair drier or air gun over the dew-prone areas. This does warm the air and mirrors, which you don't want, but it's easier on your night vision and gets the dew off.

Warming It Up

After an observing session in which the telescope gets cold, you're faced with bringing it back inside and warming it up. If you live in a moist climate, dewing can be a major problem.

The best treatment is to bring the telescope inside to a cool porch or foyer and let it adjust there before bringing it in all the way. It's even better to store it in a cool area all the time, in fact, because you'll be ready to observe more quickly if the tube is pre-cooled.

Keep the tube tightly capped or covered so that warm moist air never reaches very cold optical parts. They can warm up slowly; they'll never be so much colder than the surrounding air that dew can form. If you must bring it all the way inside, place the tube horizontal in an out-of-the-way place. If dew does form, don't wipe it off — let it dry by itself.

Pre-Cooling

Rather than waiting an hour or more before you can begin high-resolution observing, you may prefer to keep your telescope in a cool but protected place. A porch, balcony, garage, or chilly back hall may be just the thing. Be careful, though, because you don't want to go outside to find your telescope missing.

These areas tend to be dustier and grittier than the living areas of a house, so keep the tube closed with tube caps of some kind so the optics stay clean. Aside from the caps sold especially for telescope covers, you'll find elasticized shower caps or garbage bags do a pretty good job of keeping dirt out.

— *Richard Berry*

ASTRONOMY REVIEWS

Astronomy with Binoculars

James Muirden
156 pages (illus.), hardcover, $8.95
Thomas Y. Crowell Publishers (1979)

"Serious astronomical research" often conjures up images of huge telescopes with massive mountings, contained in white domes atop mountain peaks or in desolate areas where peace and solitude aid intense study. These images are, of course, not incorrect, and it is with these vivid pictures in mind that amateur astronomers, especially the novice, feel hopelessly unimportant when the words "significant discovery" roll around.

But for James Muirden, author of *Astronomy with Binoculars*, and for many others like him, the joy of discovery is within easy reach. In the foreword of this new book (first published in 1963) Muirden speaks of "...an awareness that interesting and even useful astronomical observations can be made effectively with the relatively very small aperture that conventional binoculars offer...." He goes on to state that some fields of astronomical endeavor can "achieve results denied larger instruments." An example of this is the discovery of a nova, using a pair of binoculars, by G.E.D. Alcock in 1967. A second nova was found shortly after through the same technique. By 1976, Alcock had found his fourth exploding star using binoculars, and a colleague added a fifth to the list a year later. With these impressive achievements in mind, Muirden has revamped his earlier book, and suggests that a new generation of amateur observers are utilizing an old tool for new and exciting purposes.

The first chapter discusses binoculars and telescopes in an easily read and understood style. Although some prior knowledge of optics is useful, the author explains optical theory and workings so well throughout this chapter that even a total newcomer can comprehend just how binoculars are advantageous for celestial viewing. Also included in chapter 1 is a brief discussion on the included star atlas, and some good, helpful hints on observing in general.

From here, Muirden takes the reader on a swift but very informative tour of the universe, beginning with the Sun. Included in chapter 2 are methods of solar projection and filter observation, observations of sunspots, solar eclipses, and other solar phenomena easily seen with binoculars.

A lengthy discussion of the Moon constitutes chapter 3. Topics include lunar data, phases, and surface features. After this, the various phases are again explained in more detail, with interesting and useful facts, features, and maps included. A discussion of lunar eclipses and occultations rounds out the chapter.

Chapter 4 is devoted to the planets, including the asteroids. Muirden lends his practical observing experience to the reader in this chapter especially well. All facts are accurate and well suited to the discussion. A new observer would have little difficulty understanding and applying the knowledge to his observing. Each planet is treated independently. Orbits, visual appearances, and related phenomena are clearly and expertly described. Also included here are excellent tables containing forthcoming elongations of Mercury and Venus, future oppositions of Jupiter, Saturn, and Mars, along with diagrams to help explain certain other planetary phenomena.

Comets, meteors, and aurorae are the subject of chapter 5. There should be no question in the reader's mind how, what, or where to observe these celestial wonders after reading Muirden's discussion about them.

The author leaves the solar system to journey around the stars and galaxy in chapter 6. The Milky Way and its stellar components are scrutinized, and an introduction to the constellations given. Also presented in detail are star identification methods, stellar magnitudes, celestial positions, the seasons, and sidereal time.

The real highlight of the book comes in chapter 7 as the reader begins a trip through the constellations, both northern and southern. Eight well-detailed star maps are included at the end as an atlas to aid in locating the objects described in the text. Representatives of every celestial object are selected and a short description is given for each.

The book concludes with chapter 8: "Programs for Binocular Observers." In the final section, Muirden suggests possible projects for budding binocular observers to help utilize the skills developed. Topics included range from variable star observation to nova hunting and "telescopic" meteors. Illustrations and background information help explain to the reader how to get started down the road to new discoveries.

Astronomy with Binoculars is an excellent book for the beginning observer. With prices of even basic 6" reflectors beyond the pocketbooks of many, binoculars represent a refreshing alternative and an easy way to familiarize yourself with the beautiful world of astronomy. Nor are beginners the only ones able to benefit from Muirden's book. Nearly every experienced observer has had the misfortune of transporting, unpacking, and setting-up bulky telescopic equipment only to have clouds roll in five minutes later. Packing along a simple pair of binoculars to an observing site is very easy and can *provide more observing time* with far less hassles than a telescope.

Astronomy with Binoculars deserves

a place on every amateur astronomer's bookshelf. It is well worth the investment, and will prove to be an excellent starting point for the beginner and a source of inspiration for the more advanced observer. *Dan Koehler.*

The Facts on File Dictionary of Astronomy
Valerie Illingworth
378 pages, hardcover, $17.50
Facts on File (1979)

Like any subject, astronomy is well-equipped with a vocabulary of jargon and special-use terms — many of which are obscure, infuriatingly vague, or just plain mysterious to the uninitiated. Here is where dictionaries are valuable, and this one will be useful to many who find they balk at terms like *Hirayama families* ("...groupings of minor planets whose members orbit at approximately the same distance from the Sun and have similar orbit characteristics...") or *regolith* ("...the layer of dust and broken rock, created by meteoritic bombardment, that covers much of the surfaces of the Moon, Mars, and probably many other bodies in the solar system...").

Astronomy of the Ancients
Kenneth Brecher and Michael Feirtag, editors
206 pages, hardcover, $12.50
MIT Press (1979)

"Ancient astronomy" used to mean Greek, Egyptian, or Babylonian studies of the stars and cosmos. Now it has come to refer more to the astronomical knowledge of prehistoric or preliterate societies. The lack of written accounts has forced scholars to work mostly from interpretations of physical remains: monuments and pictographic inscriptions, and naturally enough this has led to some very sharp disputes.

Yet behind all the wrangling over details, a consensus of opinion has been emerging over the last few decades that ancient (or archaic) man was a lot more observant and had constructed far more complex cosmologies than he's been credited with. The easiest trap to fall into is to assume they were dumb because they lacked the gadgets we use to poke into nature's secrets.

This book is a collection of eight articles that have recently appeared in *Technology Review*. The authors offer interesting and relatively elementary discussions of topics covering the basic astronomy of Stonehenge (Owen Gingerich), medicine wheels and Plains Indian astronomy (John Eddy), the first scientific instruments (Sharon Gibbs), pictographs and petroglyphs of the Southwest Indians (John Brandt), naked-eye astronomy (Anthony Aveni), linguistic clues in myths (Harald Reiche), and others.

Perhaps the strongest impression you get from this book is a sense of excitement on the researchers' part. While all the details aren't clear (and may never become so), the pieces are starting to fall into place. This isn't a subject full of drama and spectacle like the search into our own cosmology, but gives each of us a look behind the dry artifacts into the workings of human minds we'll never know in any other way. *Robert Burnham.*

What's Up?
David H. Olson
64 pages, spiral bound, $7.95
(order from author at 1787 W. Minnehaha, St. Paul, MN 55104)

Subtitled "an hourly guide to selected astronomical objects," Mr. Olson has put together a guidebook of objects at or near the meridian for each hour of sidereal time. The guide is produced in versions for latitudes 30°, 35°, 40°, 45° and 50° north. A table is provided which allows easy conversion from clock time to approximate sidereal time for any day in the year. In each hourly section, he lists objects (including the whole Messier list) arranged by type. In addition to the expected R.A. and Dec., altitude and azimuth are also given, as are angular diameters where appropriate. Some simple sky maps are at the end.

Solar System
Peter Ryan and Ludek Pesek
224 pages, hardcover, $19.95
Viking Press (1979)

Aimed to appeal to the general reader, this large-size, profusely illustrated book tells the story of the solar system from its formation until now in paintings and photographs. Each object in the system is presented by itself, and the reader is made to feel like he's browsing through an illustrated atlas.

The Cloudy Night Book
George S. Mumford
115 pages, paperback, $4.95
Sky Publishing (1979)

Subtitled "an astronomer's companion," it is "a collection of puzzles, word games, and miscellanea to while away tedious moments until the sky clears."

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The appendices provide reference tables with metric and astronomical measurements that cover the magnitude, distance from Earth, and other helpful facts about the major celestial bodies—constellations, asteroids, the nearest stars, the brightest stars, interesting double and variable stars, and star clusters. Along with extensive terrestrial and lunar data, the book includes the Meisser Catalog of over 100 interesting celestial objects.

281 pages, 6 x 9, diagrams and tables, $17.50

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AstroNews

More Pioneer Saturn Discoveries Announced

A 12th moon of Saturn, a "new ring" around the planet, and a possible 13th saturnian moon have been announced following further analysis of Pioneer Saturn spacecraft data, and NASA has released a new computer processed picture showing the best view yet available of Saturn and its rings.

The discoveries were made by Dr. James Van Allen of the University of Iowa, a Pioneer Saturn investigator and discoverer of Earth's Van Allen radiation belts.

The discoveries were made by what Dr. Van Allen calls "particle beam astronomy." This means that as high-speed subatomic particles mirror between Saturn's north and south poles many times per minute, traveling precisely known paths through the planet's symmetrical magnetic field, they form a particle beam. The beam is much like that in a particle accelerator on Earth. As the particles are absorbed by moons and ring material, the beam is cut off. The "shadows" thus cast by moons and rings in the beam are the means of discovering these objects. These shadows also can be used to measure size and position of moons and rings with instruments like the Iowa particle instrument.

Since the particles in a particular area are permanently absorbed, the shadow or cavity left under or over a moon or ring tends to last for hours — some distance along a moon's orbit, for example. Hence, this long-lasting shadow can be measured some time after passage of a moon.

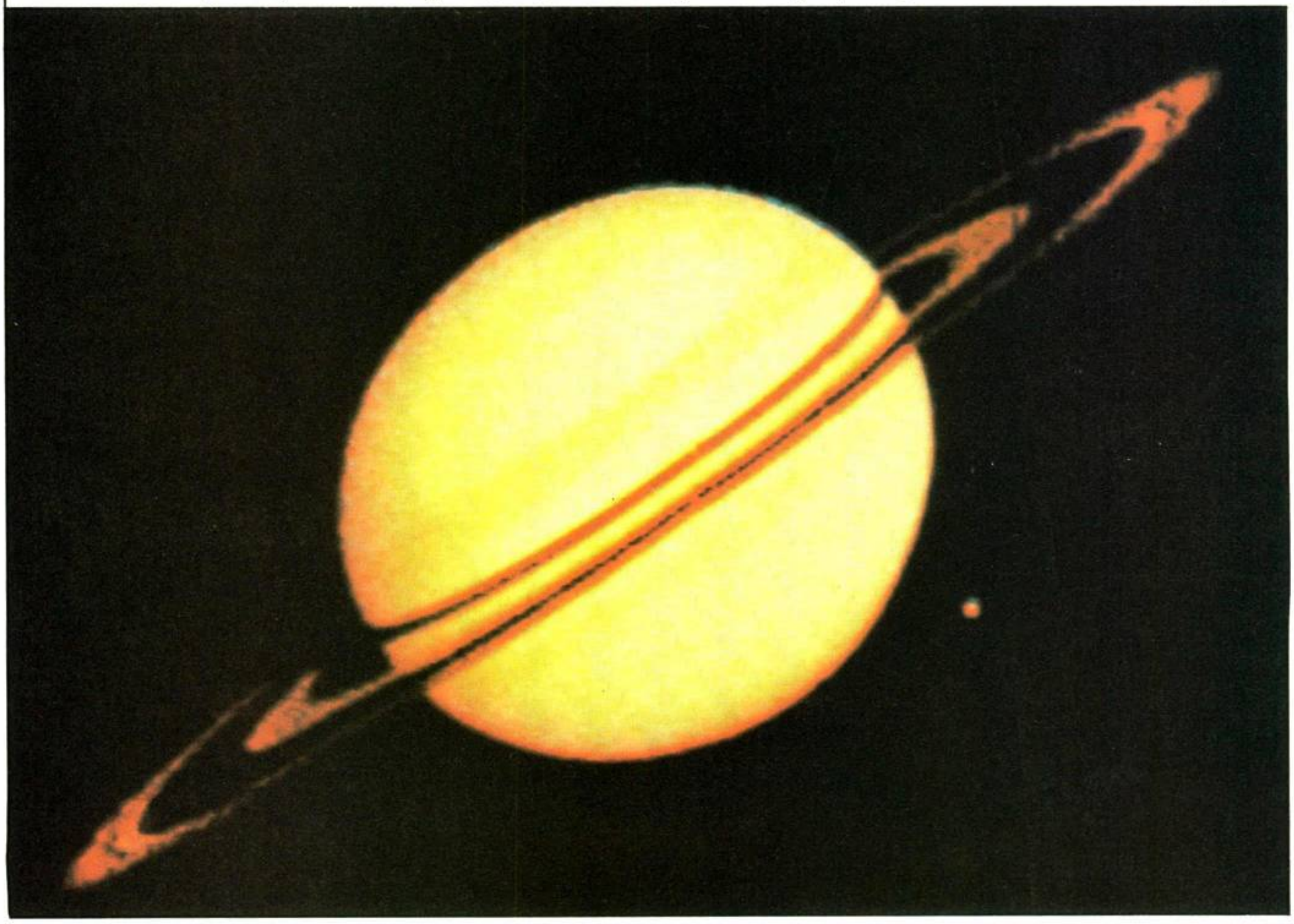
Members of the Iowa team, in addition to Van Allen, are Dr. Michelle Thompson and Dr. Bruce Randall, associate scientists, and graduate students Richard L. Rairden and Cynthia L. Grosskreutz.

The new 12th moon, designated 1979 S-5, appears to be about 170 km (105 miles) in diameter, according to Dr. Van Allen. It lies within the region occupied by Saturn's outer F ring (also recently discovered by Pioneer), and its period of revolution around Saturn is about 15 hours.

The planet's new ring is 8000 km (5000 miles) wide. At first tentatively dubbed the "G ring," it directly adjoins the outer F ring and could be considered an outward extension of that ring. However, this new ring region is 16 times wider than the F ring as measured optically by Pioneer. It is made of much more tenuous material than the F ring, and in fact may be composed of a collection of large rocks or tiny "moonlets."

In further findings, the Iowa group has made an independent confirmation of the existence and widths of the F-ring and the Pioneer Division (also found by Pioneer). The Pioneer Division separates the F ring from the outermost visible ring, the A ring. The new, more precise data show that the F ring is 2100 km (1300 miles) wide, compared with the 500 km width assigned to it by Pioneer

This view of Saturn, taken by Pioneer on August 29, 1979, is the best image of the ringed planet yet seen on Earth. NASA photograph.



optical observations.

The possible 13th moon of Saturn suggested by particle-beam measurements has been designated 1979 S-3, but data describing it can be interpreted in two ways, says Dr. Van Allen. Instead of a 13th moon outside Saturn's rings, the character of the particles themselves may be changing at this point. Work is going on to resolve this question. If it exists, the moon S-3 orbits 31,800 km (19,800 miles) outside Saturn's visible rings.

The new 12th moon and the new ring were seen twice by the Iowa instrument aboard Pioneer, both approaching and leaving the planet.

The data also confirm the existence of the 170 km diameter satellite informally dubbed "Pioneer Rock" (1979 S-2), which was observed by Pioneer at a distance of 92,000 km above the clouds within the region of the F ring's extension.

A full report of Dr. Van Allen's data was published in a special Pioneer Saturn issue of *Science*, January 25, 1980.

In various Pioneer findings of rings and moons at Saturn, optical measurements have verified particle-beam measurements, as with the F-ring, the Pioneer Division, and Pioneer Rock. However, scientists are anxious to confirm the new ring region and moons when the Voyager spacecraft flies by Saturn in November 1980.

A possible Earth-based visual sighting of Saturn's outer ring system has been reported by A. Dollfus of the Observatoire de Paris. Using a focal coronagraph with the Pic du Midi reflector to block out the light of Saturn's disk, two plates were taken on November 1, 1979. A faint line is barely visible extending eastward in the ring plane from the outer edge of Ring A (the outermost of the clearly visible rings) out to 3.40 saturnian radii, where the image of Enceladus is located. The line was not seen on the western side of Saturn. If real, this line extends well beyond the maximum distance of the Ring F extension, which Dr. Van Allen's data place at 2.550 saturnian radii from the planet's center.

The new photograph of Saturn released by NASA (see previous page) has undergone extensive computer processing to bring out detail. The view was taken by Pioneer Saturn from a distance of 2,500,000 km (1,500,000 miles) on August 29, 1979, 58 hours before closest approach. Resolution is better than Earth-based quality. The banded structure of the planet's cloud tops is evident, and the silhouette of the rings can be clearly seen against the lighted disk of the planet. Slightly above this silhouette is the shadow of the rings on the disk. Beyond the disk, structure can be seen in the rings. The rings have a distinctly different appearance in this and subsequent images than in Earth-based pictures because the rings are illuminated from below rather than from above as we usually view them from Earth.

This means that incoming sunlight is reflected from ring particles and then through the rings. If particles in the rings are too dense, the sunlight cannot get through, and that ring is dark or black. With just the right amount of particles, the rings are very bright even from the unlit side. This unique view of Saturn allows calculations of the amounts of material making up the various rings.

The outer ring A and the innermost ring C are bright, and between them the densest (and therefore brightest as seen from Earth) ring B appears dark. The Cassini Division at the inner edge of the A ring separating it from ring B is clearly resolved and is bright, demonstrating that there is in fact material present in this region. The portion of the A ring just outside the Cassini Division is dark, though, because there is more particulate matter there. The satellite seen near the planet is Saturn's moon Rhea (with a diameter of 2450 km, about one-half the size of Earth's Moon).

Scientists believe that from detailed study of this and other images they can begin to see evidence of jet streams in Saturn's upper atmosphere. The slight blue edge is an artifact from the computer-enhancement procedure.

In the processed picture, a missing segment of the outer ring due to incomplete data has been "restored" by adding ring data from the extreme outer portion of the complete ring from the opposite side.

The picture was made by the imaging photopolarimeter aboard Pioneer Saturn. The instrument separately measured the red and blue components of sunlight scattered from the clouds of Saturn and converted this information into numbers, radioed to Earth. The signals were then converted by computer into shades of gray on photographic film, and the two components plus a synthesized green image were combined into a color image very close to the planet's true color. The Saturn pictures were produced by a scientific team from the University of Arizona, while the Pioneer project is managed by NASA's Ames Research Center in Mountain View, California.

Solar System Missing Link?

Caltech planetary scientists have discovered an object orbiting the Sun that may be the missing link between comets and the class of asteroids that crosses the orbit of Earth. It has been suggested by some scientists that many small asteroids that come close to the Earth are the remains of comets that have exhausted their volatile materials which give them their characteristic diffuse heads and tails.

The object was discovered by planetary scientist Eleanor F. Helin, assisted by Schelte Bus of Caltech, both of whom have been engaged in a search for planet-crossing asteroids with Caltech Professor of Geology Eugene M. Shoemaker. The object was first detected November 15, 1979 on photographic plates taken with the 18-inch Schmidt telescope at Hale Observatories' Palomar Mountain Observatory. Since then, other observations from around the world have been used to determine the object's orbit and physical characteristics.

The object, designated as 1979VA, orbits the Sun about every 4½ years, passing from just within the orbit of Earth almost to the orbit of Jupiter (from .98 to about 4½ astronomical units — one astronomical unit being the average distance between the Earth and the Sun, or about 93 million miles). The object's orbit is inclined only 2.8° from the ecliptic (the plane of the Earth's orbit around the Sun). At discovery, 1979VA was about 13 million miles from Earth.

Orbital calculations have been done by Brian G. Marsden of the Smithsonian Astrophysical Observatory, Cambridge, Massachusetts, and Dr. James G. Williams of Caltech's Jet Propulsion Laboratory (JPL). More than 20 observations from telescopes in the U.S., France, New Zealand, England, and the People's Republic of China were used in Marsden's calculations.

On November 16, planetary scientist Alan Harris of JPL obtained photometric observations which show that 1979VA has an almost neutral gray color. Thus, it may be composed chiefly of dark carbonaceous, rocky material comparable to rare black carbonaceous meteorites. If the object is indeed dark, as suggested by the color observations, the diameter obtained by measuring the light reflected from it would be several kilometers. Harris also found that the object appears to rotate once every few hours.

Comets are relatively small, icy bodies that move in highly eccentric elliptical orbits about the Sun. They spend much of their lives completely frozen and inactive in the far reaches of the solar system. But as they approach the Sun, its heat evaporates volatile

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AstroNews

materials such as water and ammonia from their surface, creating a temporary atmosphere, or coma. These gases are ionized by ultraviolet light and blown by the solar wind into a tail of dust and rarefied fluorescent plasma.

Some comets are captured into short-period orbits, which lie mainly within the orbit of Jupiter, by close approach to that planet. A number of scientists, principally Ernst J. Opik of the Armagh Observatory, Northern Ireland, Dr. George W. Wetherill of the Carnegie Institution of Washington, and Dr. Shoemaker have theorized that many asteroids with highly eccentric orbits which approach Earth may be the remains of short-period comets from which nearly all the ice evaporated. Currently, several astronomers are searching for trace amounts of gas escaping from 1979VA.

Because the orbit of the new object passes at times within the gravitational sphere of influence of Jupiter, its orbit is probably quite unstable. Eventually, perturbation by Jupiter's sphere of influence may lead to ejection of 1979VA from the solar system. It is also possible that 1979VA may eventually collide with one of the terrestrial planets — Mars, Earth, or Venus.

The asteroid search that resulted in the discovery of 1979VA is supported by NASA's Planetary Geology program and by the Hale Observatories, which is operated jointly by Caltech and the Carnegie Institution of Washington. The search, begun in 1973, has resulted in the discovery of hundreds of new asteroids, including seven that cross the orbit of the Earth.

Starspin and Planets

In our galaxy, a giant pinwheel containing hundreds of billions of stars, we know for certain of only one star that has planets. That star is our own Sun, and the planets are those in our solar system.

Even with powerful telescopes, no one has ever seen a planet orbiting another star. It's very likely that other planets do exist, but the search for them is difficult because planets are relatively small and faint. As seen from Earth, even large planets would be drowned in the fiery light of the stars around which they move.

But aside from simply looking, there are other ways to check on the existence of planets orbiting other stars. A new way has been suggested by a University of Texas astronomer, Dr. Myron Smith. He believes that the rate of the Sun's rotation gives a clue to the presence or absence of alien planets.

The Sun's rotation has been well known for centuries. It makes one complete turn in about 27 days. Less well known is the rotation rate for other stars. Smith's study, made possible with a new high-resolution spectroscopic light-detector called a Reticon, used at the McDonald Observatory's 107-inch telescope, involved a careful look at 17 stars. Although most of these stars are about the same age and temperature as the Sun, Smith found that they generally rotate much faster than the Sun.

"The Sun is rotating two and one-half times more slowly than you'd expect for stars of its type and age. Statistically speaking, it's in the lower four to ten percent for the speed of its rotation," said Smith. He added that only one of the 17 stars he observed rotates more slowly than the Sun, and that star is apparently older. Stars are born with rapid spin, and the Sun's planets were almost certainly necessary to slow its early high rate of spin.

"Most of the angular momentum in the solar system is locked up in the planets," said Smith. Angular momentum is a measure of a body's rotational motion. In other words, if the Sun didn't have planets, it would spin much faster.

Thus, Smith suggested, the rapid rotations of other stars may indicate that the stars don't have planets, or at least not big ones. "There may be a comparative lack of Jupiter-sized planets orbiting these stars," he said.

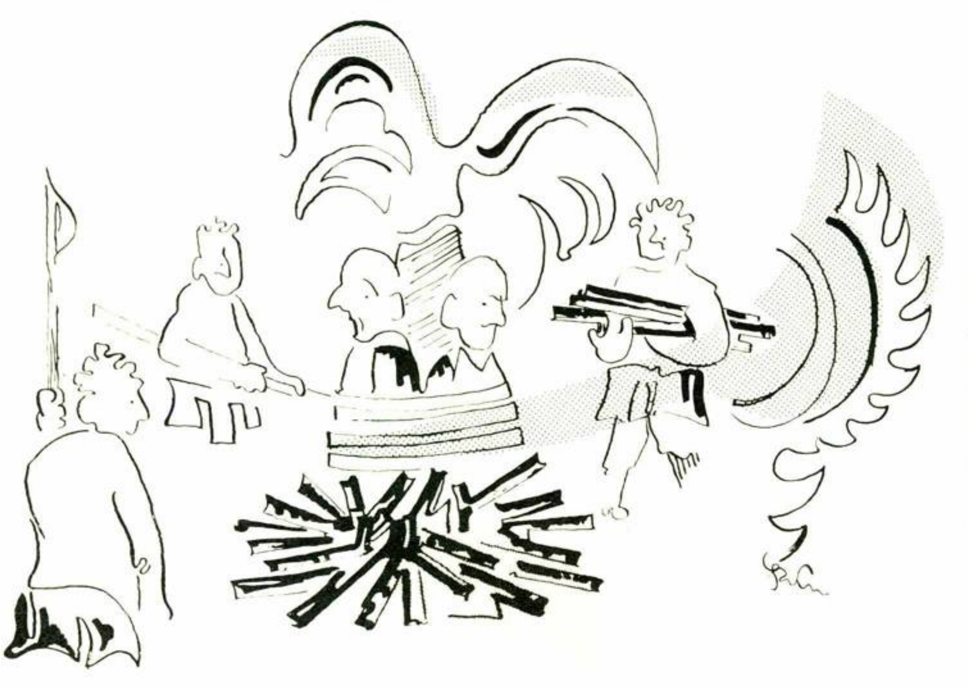
Another aspect of Smith's study may indicate that, in some cases where planets are present, the planets could have trouble supporting life.

"Rapidly rotating stars tend to have stronger magnetic fields and greater chromospheric activity," he said, adding that the chromosphere is a hot upper layer in a star's atmosphere. "For example, the nearest star to the Sun is Alpha Centauri. We know a great deal about it because it's close. It has been shown that it's rotating more rapidly than the Sun and yet has stronger chromospheric activity for its age."

Smith believes that this stronger activity in rapidly rotating stars may affect the development of life. "More active stars would produce more high-energy radiation. It's possible that on some planets orbiting these more active stars life couldn't have gotten firmly started. The reason is that the bombardment of high-energy radiation from the stars might have been lethal to early forms of life because of rampant mutations that would not allow a stable species to develop."

"But," he was careful to add, "it's also possible that moderate radiation would have caused mutations allowing biological evolution to proceed faster or along much different lines on other planets than it has around a relatively peaceful star like the Sun."

"It's important to caution that we don't know the ideal rate of mutation, or whether that phrase even has any meaning to the biologist," he said. "But this connection is a new factor to consider in trying to estimate the prevalence and forms of life elsewhere in the galaxy."



I'll admit the location isn't ideal, but at least we'll see the eclipse.

New evidence indicates the Seyfert galaxy NGC-4151 may have a massive black hole at its center. Hale Observatories photo.

Black Holes in Seyfert Galaxies?

It has been recently shown that enormous amounts of energy can be extracted from the region of space surrounding a rotating black hole by a relativistic process known as the "Penrose Photoproduction Scenario" (PPS). The details of PPS have been worked out mathematically by Dr. Minas Kafatos of George Mason University (Fairfax, Virginia) and Dr. Darryl Leiter of the Gamma Ray Astronomy group at NASA's Goddard Space Flight Center (see "Rotating Black Holes," AstroNews, November 1979).

According to this theory, rotating black holes could be the power source at the centers of active galaxies, Seyfert galaxies, blazars, and quasars. Now Dr. Leiter has reported the possible identification of just such a black hole at the center of the Seyfert galaxy NGC-4151. According to Dr. Leiter, "It is possible that confirmation of the Leiter/Kafatos theory of Penrose Photoproduction might come not only through the NASA Gamma Ray Observatory [to be placed in orbit by the Space Shuttle in the early 1980s], but also through presently conducted gamma-ray observations with balloon-borne gamma-ray telescopes."

Such balloon-borne telescopes have observed energetic gamma-ray bursts coming from NGC-4151. The spectral characteristics of these bursts of radiation, according to Dr. Leiter, are identical with those predicted by the PPS theory, assuming that there is a gigantic rotating black hole at the center of NGC-4151 with a mass of 300,000,000 suns.

According to the Leiter/Kafatos theory, a massive rotating black hole at the center of a galaxy would be surrounded by an accretion disk with a very hot, thick inner region. This inner region would be very unstable and turbulent, and from time to time extremely hot plasma would be injected into the region of space just outside the event horizon of the black hole. This region of space is known as the *ergosphere*, and it is possible for some of the material entering the ergosphere to exit with a greater energy than it had upon entering. This excess energy is "extracted" from the rotational energy of the black hole.

The result of this process would be a fluctuating blast of high-energy radiation emitted from the core of the active galaxy. This radiation would have certain identifying characteristics, some of which have now been identified in the gamma-ray spectrum of NGC-4151.

Kafatos and Leiter further suggest that 3C 273 may have a rotating black hole at its center with a mass of 3 billion suns, but observations to confirm the high-energy spectral characteristics expected will have to await the launch of the Gamma Ray Observatory, which will also provide important additional data on regions of the spectrum of NGC-4151 not yet seen by balloon-borne instruments.

A Cosmic Supercluster

Using data obtained from high-flying NASA aircraft, scientists believe they may have discovered evidence for the largest cluster of galaxies ever known. And if the indirect evidence is correct, this means they have found a huge irregularity in the distribution of matter in the universe which seems to go back to the beginning, the original Big Bang.

Scientists admit that the new evidence is exciting and that one explanation is a supercluster of galaxies. However, they emphasize that the findings are preliminary, and there are other possible explanations.

Evidence for the supercluster of galaxies, and hence for the huge irregularity, comes from analysis of measurements from NASA U-2 aircraft of the cosmic microwave background radiation left over from the Big Bang.

In 1978, a NASA-University of California at Berkeley team used the instrumented aircraft operated by NASA's Ames Research Center to survey remnants of such radiation in the entire northern hemisphere sky. A similar survey of the southern hemisphere has just been completed.

The University of California scientists used this U-2 data to conclude that the Milky Way Galaxy — of which we are a part — is hurtling toward the constellation Virgo at more than a million miles an hour. This speed, which is much faster than expected, is attributed to the pull of the supercluster around Virgo.

The research group believes the supercluster contains 30 to 40% more galaxies than normally found in the same volume of space, and that it may stretch across some 2 billion light-years of space. When compared to the 10 billion-light-year-radius of the observable universe, the supercluster would encompass 1% of its volume.

Dr. George Smoot of the University of California noted that not enough time has passed since the Big Bang for such a supercluster to have formed. This means that such a gigantic concentration of mass could go back to the beginning of the universe.

The surveys by NASA aircraft suggest that the event which started the universe about 10 billion years ago was extremely regular, that is, a powerful but tightly controlled expansion with matter moving outward in all directions at an equal rate.

Now comes the possibility of the supercluster and, "if we have one such huge concentration of matter," said Smoot, "there are probably others." This implies that at the time of its formation, the universe was "lumpy" — that the primordial fireball itself was lumpy instead of being extremely smooth as measurements by the University of California researchers and others had previously suggested.

The work of other astronomers has contributed to the suspicion of "something unusual in this part of the sky," Dr. Smoot said. X-ray astronomy studies by A.C. Fabian (Cambridge University) and R.S. Warwick (University of Leicaster) have found indications of a large-scale structure in the direction of Virgo. J.A. Tyson and J.F. Jarvis of Bell Laboratories have made automated counts of faint galaxies on long-exposure photographic plates and have found evidence of a northern supercluster of galaxies — far more than in any other part of the sky surveyed.

Scientists are surprised at the evidence for a cluster billions of light-years in diameter. Said Smoot: "It boggles the mind that such a gigantic structure could exist — a big fraction of the observable universe."

Apparently there is only one such collection of mass relatively close to us. Others, however, may be found at great distances. Despite the possible existence of these large clusters, the mass of the universe appears, on the average, to be evenly distributed.

Dr. Smoot is somewhat disappointed that the finding could disrupt the pattern of a completely uniform Big Bang, because a uniform universe history fits very well with recent work on subatomic particles. "It is a paradox," he said, "that the universe is so uniform, but yet it appears to contain non-uniform structures on very close to the largest possible scale."

The Mystery of AM CVn

Since its discovery 15 years ago, AM Canum Venaticorum (AM CVn) has remained an enigma to astronomers. The labels proposed read like a celestial zoo. AM CVn has been called a quasi-stellar object, a massive helium star, a rotating or pulsating subdwarf, a DB degenerate dwarf, and a cataclysmic binary.

An extensive program of photometric observations, at McDonald Observatory in Texas, has helped resolve some of the confusion. The program reached a peak during the spring of 1978.

Joseph Patterson and other astronomers at McDonald observed AM CVn for 74 hours over a 22 night period in the spring. "With a 30-inch reflector we collected data equal to the total collected up to that time. The weather is stable in Texas during this period and AM CVn was well placed in the northern sky," commented Patterson at a recent colloquium held at Smith College in Massachusetts.

An analysis of the new raw data confirms the existence of a unique binary star — a cataclysmic variable undergoing a phase of extremely rapid mass transfer. Cataclysmic variables are binary stars in which mass is being transferred from a large, cool star onto a white dwarf. In the case of AM CVn, the low-mass secondary star orbits the primary white dwarf star in about 17½ minutes. This is the shortest period of any known binary.

The primary star is a white dwarf about 70% as massive as our Sun. The secondary has only 4% of our Sun's mass. The entire binary system could fit inside Jupiter with room to spare.

When Patterson's data were compared to previous observations of AM CVn, an orbital period increase of 0.012 second each year was also discovered. "An orbital change of this magnitude is three to four times greater than any known binary star. It indicates a continuous mass transfer from the degenerate secondary to the primary," reports Patterson in the September 15, 1979 issue of *Astrophysical Journal.*

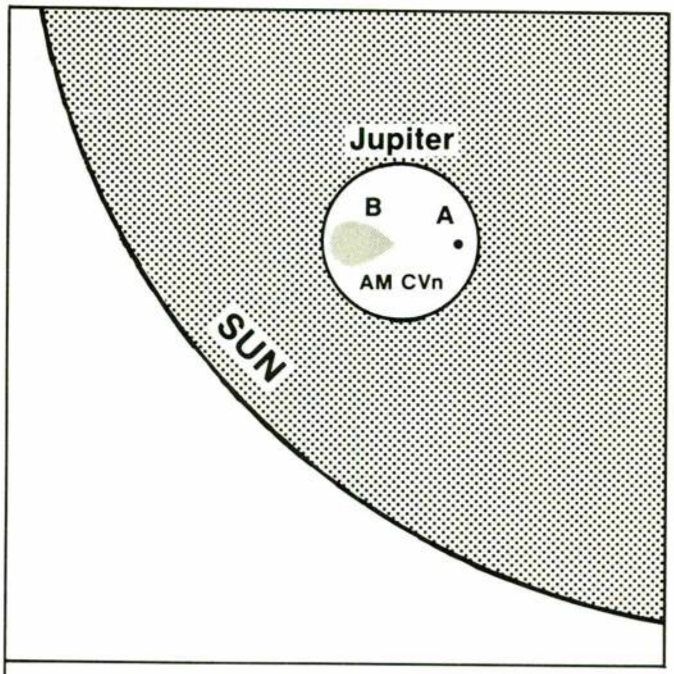
As the secondary loses mass to the primary, its diameter will increase. The mass loss will also result in a loss of angular momentum in the binary system. This, in turn, results in the rapid increase of the orbital period.

According to Patterson, the actual mechanism of mass transfer is not yet known. There is, however, spectrographic evidence that an accretion disk of helium around the primary does exist. Because the secondary is in an advanced stage of degeneracy, only the helium at the star's original core would remain. This helium secondary takes on a pear shape with the narrow end pointing at the primary star. This shape is the same as that of the Roche lobe, defined by the balance of gravitational forces in the system.

"Right now the expansion of the secondary filling its Roche lobe is barely keeping pace with the increasing distance between the two dwarfs. In about 100,000 years the secondary will be unable to supply any more matter. It will have expanded to its maximum diameter but contain only 1/10 of 1% of our Sun's mass," said Patterson.

When the mass "pump" shuts off, the exotic binary in the constellation Canes Venatici will become a white dwarf circled by a much larger giant planet — the burned-out core of a star cannibalized by its companion.

What about AM CVn's past history? At one point gravitational radiation may have played an important role in the orbital dynamics of the binary. "The orbital period may have decreased to only five minutes prior to the beginning of mass transfer," estimates Patterson.



The scale of the peculiar binary star AM Canum Venaticorum (AM CVn) is shown in the diagram above. The entire system could easily fit inside the planet Jupiter.

Two other major questions (in addition to that of the mechanism for mass transfer) still remain unanswered. First, the distance to AM CVn is very poorly known. Estimates run from 500 parsecs (1600 light-years) to 4 kiloparsecs (13,000 light-years). The other question involves a regular 26 second pulsation of the primary, which may indicate rotation of the star. If the actual spin rate is less than 50 seconds, according to one theory, the explanation for the observed orbit period change would be more complex.

An expanded observation program is being planned for the next few years. Besides collecting more photometric data, a search for extreme ultraviolet, soft X-ray, and hard X-ray emissions will be undertaken. Unconfirmed reports indicate hard (high-energy) X-rays are coming from AM CVn. This type of emission is known to occur in other cataclysmic binaries.

In conclusion, Dr. Patterson pointed out how fortunate we are to have found a binary in such a short-lived phase of evolution. Out to about 3,260 light-years (one kiloparsec) it is estimated that no more than 10 cataclysmic binaries are in the active AM CVn phase. These 10 potentially visible binaries constitute only 1/100 of 1% of the estimated 100,000 catacylsmic binaries within one kiloparsec, the rest being inactive in terms of mass transfer but each a potential solar system consisting of a very unusual planet.

Resources for History

It is becoming increasingly difficult for most existing institutions to keep pace with current developments in astronomy and also maintain orderly programs for the preservation of the history of astronomy. Budgetary and space considerations almost always result in historical preservation being relegated to a low priority. But the records of earlier astronomers are of genuine value. Such records are often important to current research as well as for understanding the past and formulating policies for the future.

To answer this need, a new center devoted to the history of astronomy has been founded. Known as the History of Astronomy Resource Center, it will concentrate on materials relating to developments in astronomy in the United States during the 19th and early 20th centuries. According to Paul W. Luther, director of the center, materials from this period are presently in danger of being lost forever.

The center, currently located in Bernardston, Massachusetts, is accepting applications for both individual and institutional memberships. Services to members include access to a research and bibliographic directory, a reference library, and a plate and illustration library. In addition, the resource center will maintain a union list of books and documents which are in the libraries of participating private parties. Such a list, which Luther describes as the "heart of the resource center and its fundamental rationale for existence," will make it possible to identify valuable resources for research in all parts of the country.

Publications of the center will include *Books and Astronomers Monthly*, a biographical and bibliographical reference work in a looseleaf format. Now in its second year, each issue of the *Monthly* gives an extensive chronology and brief commentary on the life and work of one astronomer or popularizer of astronomy, and includes a detailed bibliography of the books and separately published pamphlets written by the subject. Arthur S. Eddington, John Herschel, Edwin P. Hubble, and Johannes Hevelius were among the subjects of Volume One, already published. Volume Two will be devoted strictly to English speaking astronomers.

A quarterly newsletter providing a review and discussion of issues of interest to scholars, collectors, and librarians with reports on the progress and growth of the center will also be published.

Other services of the center will include expert assistance in evaluating the historical and financial value of books and documents relating to the history of astronomy and a book search service. The center will also buy and sell used, rare, and out-of-print astronomy books, providing an additional source of regular operating income. About four catalogs of available books will be issued each year.

Those interested in learning more about the center should write to:

The History of Astronomy
Resource Center
P.O. Box 262
Bernardston, MA 01337.

Asteroids in London

The Royal Astronomical Society of London devoted a recent meeting (November 1979) to the asteroids. These small rocky bodies mainly orbit between Mars and Jupiter, and the largest of them is Ceres, discovered over 180 years ago on the first night of the nineteenth century. It is 550 kilometers in diameter and has a mass only 0.02% that of the Earth. Only a few years back most astronomers regarded the asteroids as a rather boring collection of debris. A flood of data, coupled with the realization that the asteroids are a relic from the hazy early history of our solar system, has turned research on the minor planets into a lively subject.

Truly accurate diameter measurements now exist for a handful of asteroids. Gordon Taylor of the Royal Greenwich Observatory presented the main conclusions from three occultation studies at this meeting. (When an asteroid crosses the line of sight to a star, the star's light is blocked for a few seconds. This event is an occultation. They are rare and to be observed must be predicted accurately.) Taylor has spent 27 years perfecting a prediction method so that the timing of occultations can provide data on the sizes of asteroids.

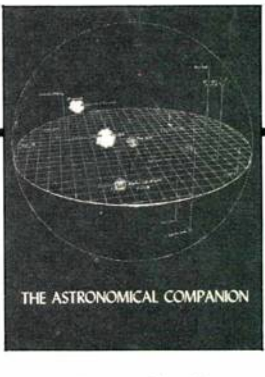
In 1978 observers from New England to Oregon timed an occultation caused by Pallas. It yielded a diameter for Pallas of 538 kilometers, with an accuracy of 2%. The fact that Edward Barnard (1857-1923) got to within 10% of this value in 1894 is a fine tribute to that great observer.

The Lowell Observatory made an occultation measurement of Herculina which turned out to be very intriguing to the experts because a double occultation occurred. Herculina is 217 km across and it seems to be accompanied by a small satellite 45 km across. Similarly, an occultation of Melpomene, observed in the southwest U.S. in December 1978, implies the presence of a tiny moon (see ASTRONOMY AstroNews, March 1979). The vast improvement in computer predictions will enable many more occultations to be timed in the future, an activity in which the advanced amateur can assist.

David Hughes of Sheffield University has been figuring out the combined mass of the minor planets by simply adding up those we know about and making an intelligent guess about the rest. It's hard to find more than one-thousandth of an Earth mass out there, which would rule out the idea that the debris is all that remains of a real planet. Theorists are converging on the notion that the asteroids are a valuable relic of the early solar system. When the planets were first formed, a great many rocks and stones were initially left stranded. Subsequently most of these collided with larger bodies, forming craters on Mercury, the Moon, and Mars. But in the large gap between the orbits of tiny Mars and massive Jupiter the asteroids have survived.

Most meteors are fragments expelled from the asteroid belt, according to E. Anders of the University of Chicago. By matching asteroid data to meteorite properties it is possible to learn more about the former. Ed Bowell of the Lowell Observatory observes the colors and brightnesses of asteroids. He explained that six main varieties, each matching a meteorite type, are now recognized. Brightness data indicate that while some asteroids are whiter than natural chalk, others are darker than coal. Another finding is that families of asteroids which share the same orbit also have the same compositions. This shows that the families are fragments from collisions of large asteroids.

Anders explained that careful study of meteorite craters on the Earth hints at an origin in the asteroid belt. For example, Clearwater Lake in the province of Quebec is a crater 200 million years old (see photo in AstroNews, September 1979). Rocks melted on impact have minerals associated with the asteroid belt. Other researchers have pointed to comets as the source of meteorites. While this may account for some of the major showers, comet debris seems to be too cinderlike to explain structures like Clearwater Lake.



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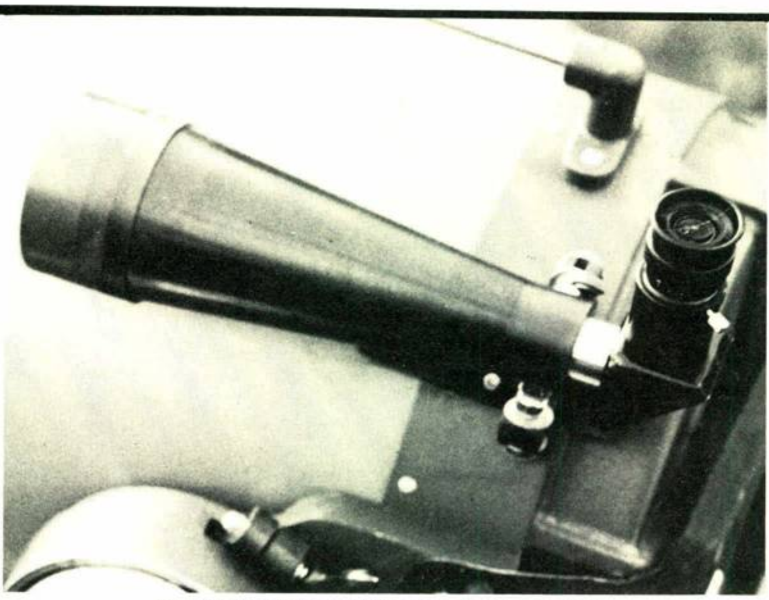

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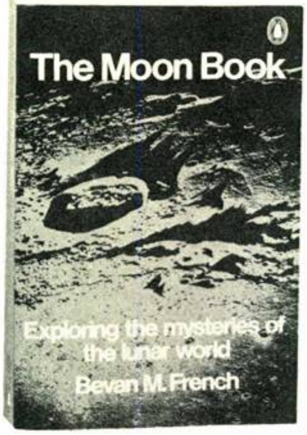

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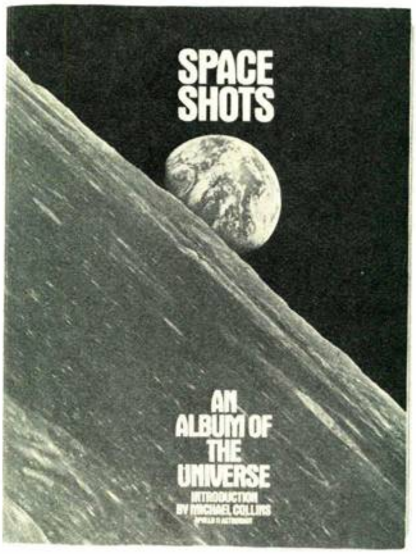

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Fred Hapgood

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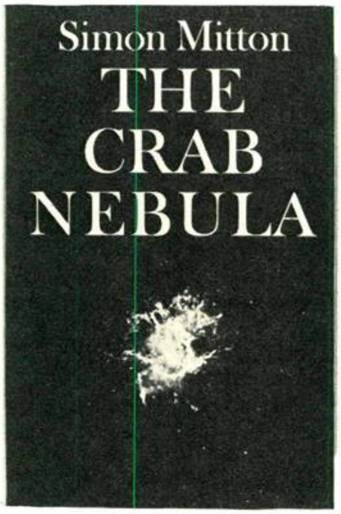

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ASTRONOMY *bookshelf*

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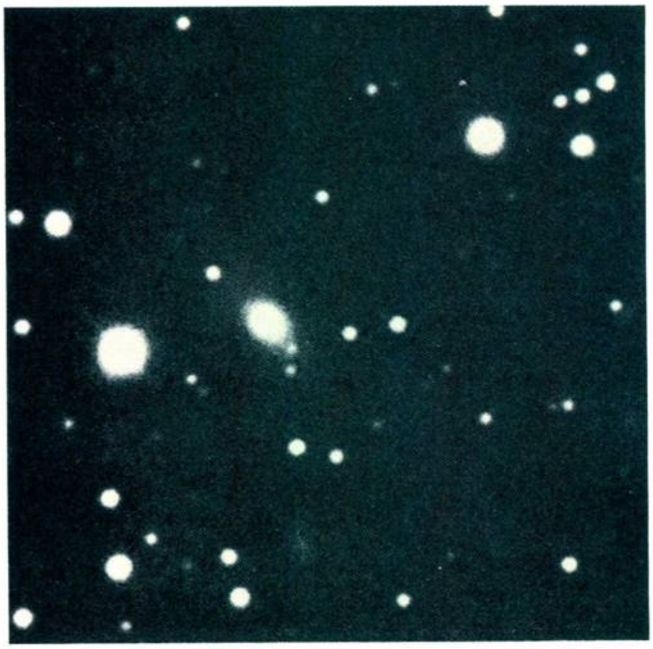
Are Blazars Quasars?

by Jack R. Schendel



BL Lacertae **Kitt Peak National Observatory**

Far out in the cosmos lie strange objects called blazars. These objects are the most violent and at times the most luminous objects in the universe. Ranking high on the list of modern astronomy's greatest mysteries, blazars have recently been the subject of intensive study by optical astronomers, radio astronomers, and theoretical astrophysicists.

What are blazars? What characteristics make them so unique and fascinating to astronomers today, and so important for extragalactic astronomy? Why do some scientists suspect that blazars may even be the key to understanding quasars (quasi-stellar objects), the enormously powerful and perhaps most distant objects in the universe?

Blazers is a term coined by Columbia University's Ed Spiegel for objects that astronomers conventionally call BL Lac objects. The astronomers who discovered one in 1929 thought it was just another variable star in the constellation Lacerta, the lizard. As it was the 90th variable star discovered in Lacerta, they gave it the designation *BL Lacertae*, or BL Lac for short. No one showed any interest in this "star" until 1968 when someone discovered that BL Lac was a very powerful radio source. Shortly thereafter, many astronomers devoted a great deal of time to investigating the properties of BL Lac and a number of other objects with similar properties. By 1972 researchers suggested that BL Lac was the prototype of a whole class of astronomical objects with properties very similar to quasars.

What Are They?

Visually blazars look very much like quasars: they appear as faint starlike objects with apparent magnitudes in an approximate range from +14 to about +19. One difference between them is that blazars are frequently surrounded by small, very faint nebulosities; another is that for radio astronomers, blazars tend to appear as very compact single sources, while quasars tend to appear as double extended radio sources. By using very long baseline interferometry (VLBI) (see "Using Earth as a Radio Telescope," ASTRONOMY, October 1979), radio astronomers found that the typical apparent sizes of the blazar radio sources are on the order of a milliarc-second — no larger than a dime in Chicago as seen from San Francisco.

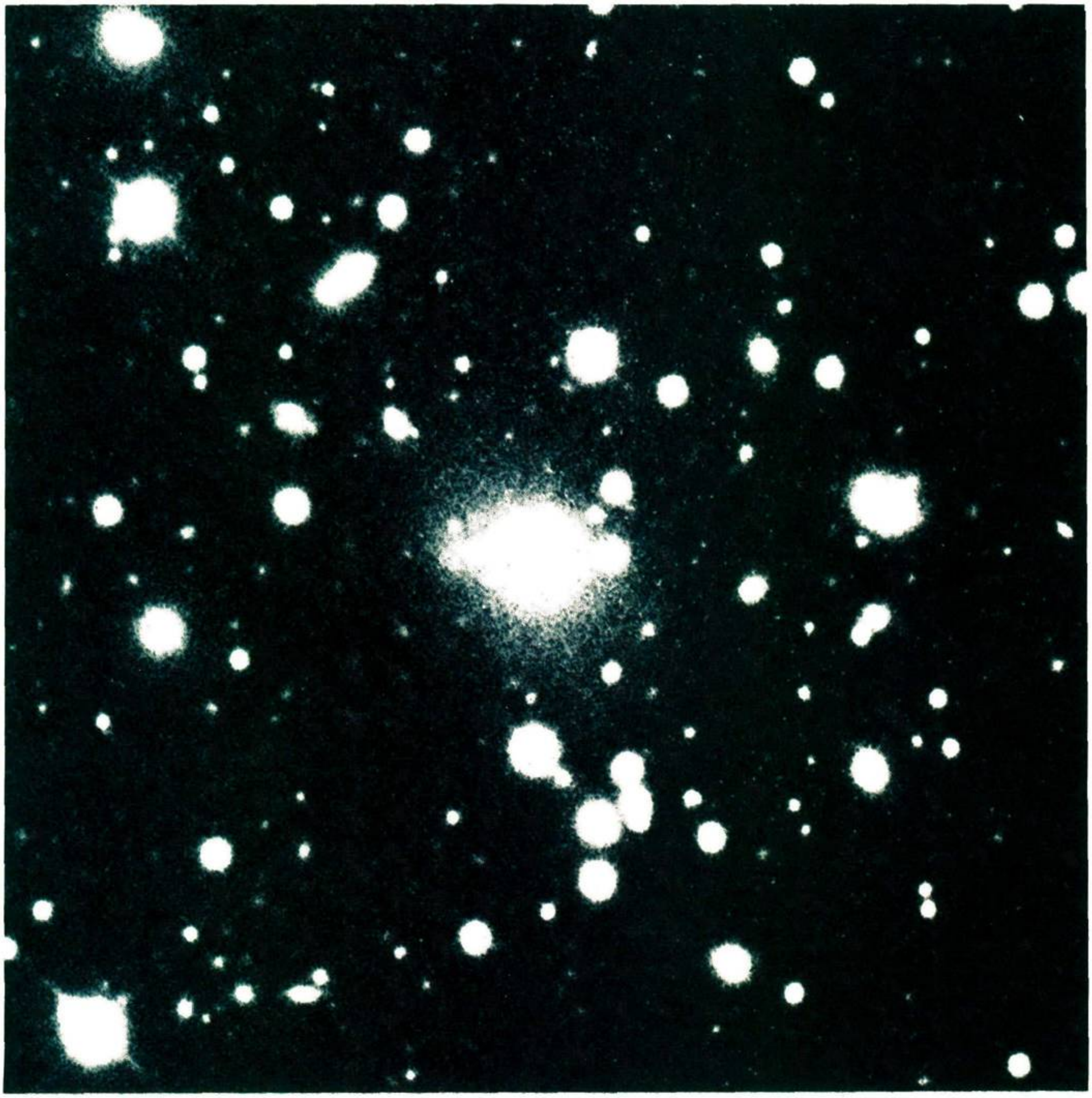
A second characteristic of blazars is that they vary greatly in their luminosity. Over a few months in 1975, one BL Lac object designated AO235+164 increased its luminosity by fully five magnitudes — a factor of 100. BL Lac itself has varied its light output by a factor of 10 in a few months' time and has changed its luminosity by as much as 50% from one night to the next. Blazars are also not immune to variations in their radio output, but the radio outbursts are not as large and, strangely, do not seem to be strongly correlated to the optical outbursts.

Along with rapid changes in optical and radio luminosities, astronomers find that the polarization of blazars is also highly variable. In polarized electromagnetic radiation (which includes visible light, radio waves, etc.), the electric field part of all the waves points in a uniform direction instead of in random directions. In both the optical and radio portions of blazar spectra, the degree of polarization is high (up to 35% optically) and highly variable (changing by as much as 5% from night to night). Additionally, even the direction of polarization varies. BL Lac once amazed astronomers by changing its direction of polarization by 12° in less than four hours.

The last defining observational characteristic of blazars is their spectra — the amount of light or radio energy they produce at different wavelengths. Their spectra are quite different from those of stars or normal galaxies. Stars have a *blackbody* or thermal spectrum. Everything (including you and the surface of a star) that is at some finite temperature gives off electromagnetic radiation. The spectrum of this thermal radiation depends entirely on the temperature. In blazars, however, the spectrum is nothing like a thermal spectrum, and so they call it a nonthermal spectrum. In particular, blazars (like quasars) have a type of nonthermal spectrum called a *power law spectrum*, which means the energy flux from these objects is proportional to some power of the wavelength.

The spectral index of an object is a measure of the energy flux received at specific wavelengths. In the optical range, the average spectral index for blazars is about 1.8 — a little higher than that of quasars. In the radio range, both quasars and blazars still have a power law spectrum, but the spectral index is about 0 for blazars and about .5 for quasars.

Another peculiarity of blazar spectra is that although they are emitting enormous amounts of energy in the optical and radio portions of the spectrums, they have little or no X-ray emission. And another thing that seemed to be missing in blazars is discrete spectral features. While many well-defined spectral features are superimposed on the nonthermal spectra of quasars, blazars had none originally. Even the very definition of a blazar once included a "lack of



This photograph of the blazar PKS 0548-322 clearly shows both the bright core and the surrounding nebulosity characteristic of these mysterious objects. The actual source of the tremendous energy emission (sometimes called "the Machine" to symbolize its unknown nature) must be extremely small. Photo courtesy of the Kitt Peak National Observatory.

spectral features" as an integral part of the definition.

Blazars, thus, have a few observational oddities that don't sound too exciting on the surface. But the real story lies in the implications — in the very physics of the universe — and in the kind of object that must exist to explain a blazar. What, then, do these properties imply about blazar structure and the physical processes taking place in these objects?

First, the rapid changes in both luminosity and polarization imply that the region which powers these objects must be very small. Whatever causes these changes must be able to do so throughout the entire region within a few weeks or months to account for the variability in luminosity. Imagine that a gnome in the center of a blazar dictates these changes: he throws a switch, making them turn on. The outer regions of the powerhouse can't possibly know the gnome's wishes quicker than the time it takes for a light signal to travel there because no signal can travel faster than light. Since significant changes occur in a few days, the central core of the blazar can't be bigger than a few light-days across — not much bigger than our own solar system. This is tiny — only a speck — when you think in terms of galactic size scales. The whole powerhouse can't be much bigger than a few light-months across to account for the variability in the luminosity. The size scales that radio astronomers get from the VLBI measurements confirm the theory that the emitting region is tiny.

The second critical finding is that blazar radiation comes from a process known as *synchrotron emission.* Synchrotron emission is the electromagnetic radiation generated when a charged particle travels in a circular or nearly circular path. Maxwell's theory of electromagnetism dictates that a charged particle will emit radiation whenever it accelerates, and any curved motion is an acceleration.

Electrons moving in a magnetic field probably cause the nonthermal spectra of both blazars and quasars. When an electron moves in a magnetic field, it spirals around the field lines as it moves along them. Because it is constantly changing direction, it is accelerating and, thus, gives off radiation.

Electromagnetic theory also predicts that this radiation will be polarized, and this explains the high degree of polarization seen in these objects. It also predicts the nonthermal power law spectrum which is observed. Variations of electron synchrotron emission have been suggested, such as proton synchrotron emission, but some form of synchrotron emission seems to be the mechanism for producing the nonthermal spectrum.

But where do these electrons come from? Where do they get their energy? What powers them? Where does the magnetic field come from? This is part of the intriguing link between blazars and radio galaxies and quasars which also have magnetic fields and spiraling particles.

How Far Are They?

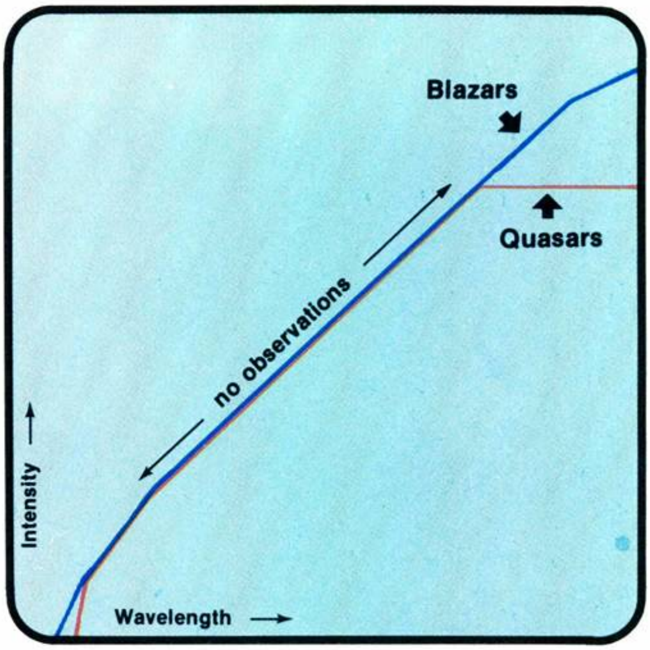
Most astronomers agree on the two deductions, namely that both blazars and quasars are very compact and that some form of synchrontron emission produces their radiation. But one important question remains: How far away are they? If astronomers could determine the distance to these objects, they could then deduce the total energy they produce.

Astronomers have a hierarchy of methods to measure distances to celestial objects, ranging from trigonometric parallax (measuring shifts in position of nearby stars from season to season) to measuring the angular sizes of hydrogen gas clouds in distant galaxies. On the extragalactic scale, astronomers often use the redshift of the object combined with the Hubble law to determine the distance to the object. For quasars, astronomers carried out this process and found that they are the farthest known objects, many literally on the edge of the visible universe. But they couldn't do this for blazars at first simply because they hadn't observed any spectral features.

Since quasars generally have many reasonably well-defined spectral features which can be identified with specific atomic spectra, their distances can be determined. But can we believe the results?

A group of astronomers — sometimes called the "heretics" — led by Geoffrey Burbidge (a well-known observational cosmologist), feel that the results for quasars should be questioned. A key point in their argument is that the Hubble law is based on normal, quiet galaxies, but quasars are neither normal nor quiet. It's possible, they argue, that the redshifts measured aren't totally due to cosmological expansion but may be at least partly due to effects intrinsic to quasars themselves, such as gravitational redshifts. These "heretics" also have another very good argument. If quasars are at the cosmological distances dictated by the Hubble law, then they have to be emitting incredible amounts of energy — so much energy, in fact, that problems arise with the model of synchrotron emission. (See "The Redshift Problem," ASTRONOMY, September 1978.)

The biggest problem in determining the distances to blazars was they seemed to have no discrete spectral features. Without discrete spectral features by which to measure redshift, astronomers couldn't deduce a distance and were left to complete speculation. But in 1974 James Gunn and J.B. Oke reported that they had found discrete spectral features and had determined a distance for BL Lac. Others questioned their report, however, when the results couldn't be reproduced. In fact, some suggested that the feature they had heavily relied upon to calculate the redshift may have actually been due to oxygen in the Earth's atmosphere.



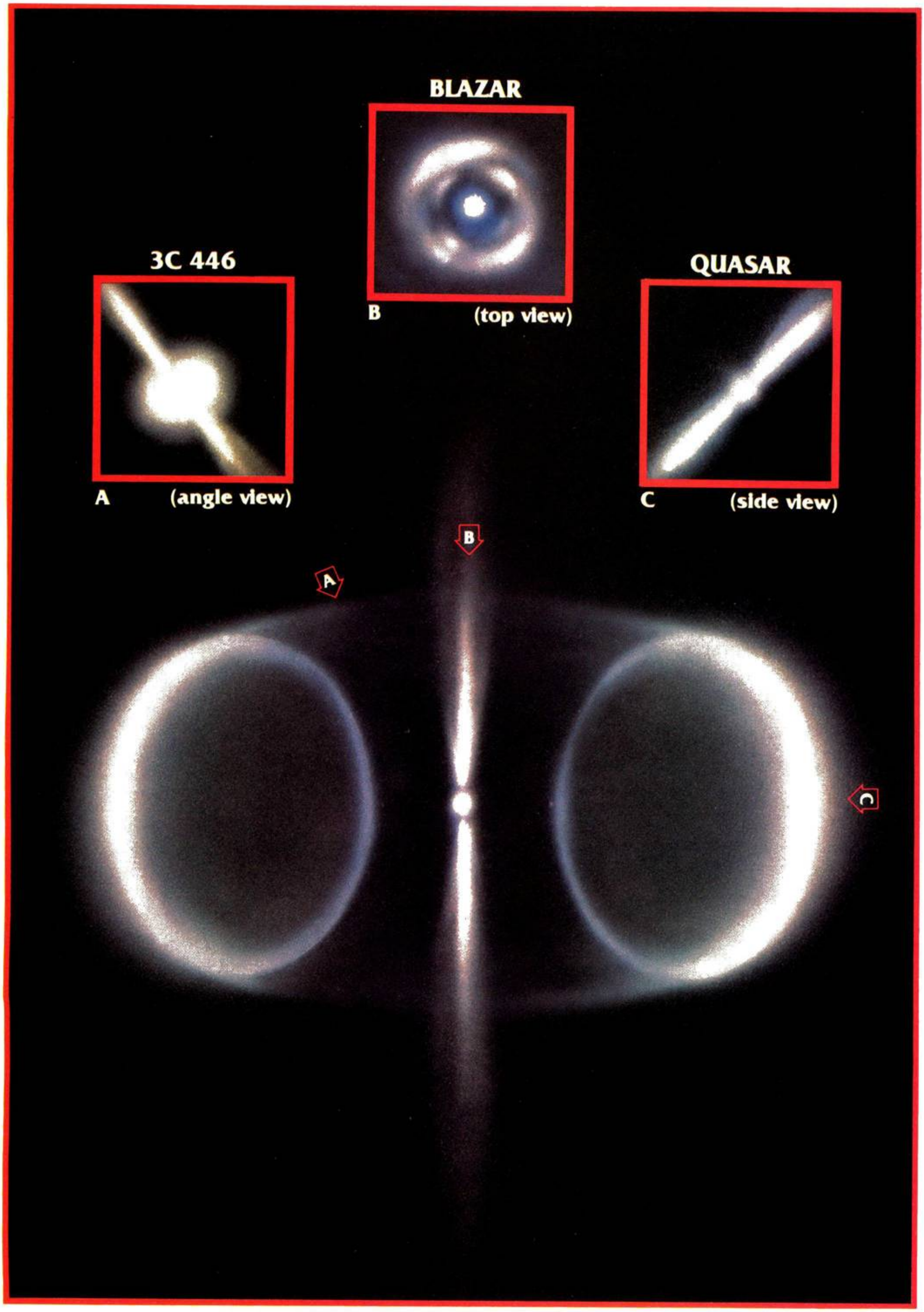
Both quasars and blazars have *nonthermal spectra* (see text). In the radio range, blazars have a somewhat "flatter" spectrum than quasars, but in the optical range, they have a slightly "steeper" spectrum. The region of the spectrum marked "no observations" is the far infrared region obscured by water in Earth's atmosphere.

This controversy would have continued if not for Joseph Miller and Steven Hawley of Lick Observatory. Late in the summer of 1975 when BL Lac was near a minimum luminosity, they observed it with Lick's 3-meter telescope. From previous experience with an object designated 3C 371, they felt that when BL Lac is very luminous, the nonthermal background might overpower its discrete spectral features. But when it's near a minimum, some underlying spectral features might be observable. Their hunch proved correct and yielded unquestionable spectral features in the core of BL Lac leading to a redshift estimate of about 0.07. This would put BL Lac at a distance near 130 million light-years. Or does it?

Once the redshift for BL Lac was known, it simply became more fuel for the redshift controversy. However, Miller and Hawley together with Howard French — aided by two nights of near perfect seeing in July 1977 — finally put the distance question for BL Lac to rest with their observations. Improving upon a technique used by Gunn and Oke, they observed the nebulosity surrounding BL Lac. They obtained a spectrum through a ring aperture which allowed the light of the nebulosity to enter their spectroscope while blocking the light from the core (which happened to be even dimmer than at the earlier observations).

The results were amazing. The spectrum matched that of a normal elliptical galaxy (they used Andromeda's satellite galaxy, M-32, as a comparison) at a redshift of 0.07. Thus they showed convincingly that BL Lac was at the center of a normal galaxy to which the Hubble law applies. BL Lac really was at the cosmological distance its redshift implied. Even more stunning was the revelation that whatever BL Lac is, it must be something happening in the core of an apparently ordinary galaxy.

Since the time of the determination of BL Lac's redshift, Miller and other astronomers have measured the redshifts of more blazars. At a conference on blazars held in 1978 in Pittsburgh, the general agreement among astronomers was that blazars are, indeed, actually located in otherwise


BLAZAR
B
(top view)
3C 446
A
(angle view)
QUASAR
C
(side view)
B
A
C

The Blandford-Rees model of blazar/quasar structure is also called the "Two Views" model because it suggests that a single type of object appears to us as a blazar if we happen to view it along the axis of its nonthermal emission, but as a quasar (with a characteristic double-lobed form at radio wavelengths) if seen from the side. Peculiar objects such as 3C 446, which seem somewhat like a blazar and somewhat like a quasar, may represent in-between viewing angles. More observations are needed to confirm or disprove the Blandford-Rees model, which is not yet fully accepted. Artwork by Mark Paternostro.

normal galaxies which are at cosmological distances.

Blazars and quasars now begin to look more and more alike. But some are still skeptical of the cosmological interpretation of quasar redshifts: Geoffrey Burbidge accepts the cosmological redshifts for blazars but still doubts that of the quasars. As he said at the Pittsburgh conference, "No one has ever shown that quasars are in the center of galaxies. The evidence isn't there." Despite these doubts, the evidence was gradually accumulating for a connection between blazars and quasars. A number of peculiar objects were found which at times had some of the characteristics of blazars, but at other times looked more like quasars (see box at right). Astrophysicists began to suspect that blazars and quasars, for all their differences, might not be distinct classes after all.

The Blandford-Rees Model and the Future

At the Pittsburgh conference, Martin Rees of the Institute of Astronomy at Cambridge (England) and Roger Blandford of the California Institute of Technology conjectured that blazars and quasars may be the same type of object. The difference is in the direction from which we view them. In their model, an optically dense cloud shaped like a wide ring surrounds a mysterious central core — perhaps a black hole? The outer fringes of the surrounding cloud, composed of a gas of atoms and ions, would produce the discrete spectral features we see. The nonthermal radiation is beamed along the axis of these objects and would not be as strong seen from the side.

All this sounds very suspicious. Can it be that two types of objects formerly thought to be distinct are in fact identical structures? There definitely seems to be an intriguing connection between quasars and blazars.

If we see such an object along, or nearly along, the axis, we would call it a blazar because the discrete spectral features would be overpowered by the powerful nonthermal radiation. If, however, we see it from the side, the spectral features due to the surrounding cloud will be much stronger and we would call it a quasar. This model also seems to explain why blazars tend to be single radio sources while quasars are generally double sources — for in the case of quasars we view the object from the side and see both beams of radiation.

The main evidence for this model lies in the fact that some objects spend some of their time looking like a quasar and some of their time looking like a blazar. BL Lac itself, at times of high luminosity, shows very little evidence of spectral features, but in times of low luminosity the spectral features do show. The best spectrum obtained by Gunn and Oke came at a time when BL Lac was considerably less luminous than the times of their other observations.

Another object, 3C 446, has been studied extensively by astronomer Joe Miller. During an outburst in 1977 he observed that the spectrum had no discernible features and it had a very high degree of polarization (15%); therefore, it looked like a blazar. However, during periods of low luminosity, it looked very much like a quasar with very prominent spectral features.

Blazar or Quasar?

The radio source 0845+51W1 has been behaving very strangely. Originally identified as a 19.5 magnitude star, it was found to be nearly four magnitudes brighter only a month later. It had all the characteristics of a blazar, including the absence of spectral lines, but as it gradually faded back down below 19th magnitude, emission lines typical of a quasar began to appear. These lines indicated a redshift of 1.86, the highest yet found in a blazar, but not unusual for quasars. Unlike quasars, though, 0845+51W1 turns out to be rather red in color — even more so when it is at its faintest.

Writing in the May 15, 1979 issue of the *Astrophysical Journal*, a group of researchers including Halton Arp of the Hale Observatories noted that 0845+51W1 lies suspiciously close to a pair of peculiar interacting galaxies. These galaxies, however, have a redshift of only 0.07, much less than that of 0845+51W1.

What is 0845+51W1? Is it a peculiar, distant blazar or an even stranger quasar? Is its redshift truly an indication of distance, or is it somehow associated with the nearby galaxies? Could it be a "missing link" between quasars and blazars? No one yet knows.

Very recently Halton Arp and Wallace Sargent of the Hale Observatories, working in collaboration with A. Willis and C. Oosterbaan of Huygens Laboratorium in the Netherlands, published a study of a blazar designated 0846+51W1 which underwent a tremendous outburst in 1975. It increased its luminosity by a factor of 40 in one month and during the height of the outburst, 0846+51W1 had no discernible spectral features and looked very much like a blazar. As the luminosity began to drop, spectral features began to appear and it looked once again very much like a quasar.

All this sounds very suspicious. Can it be that two types of objects formerly thought to be distinct are in fact identical structures? There definitely seems to be an intriguing connection between quasars and blazars.

One very significant problem remains, though. The enormous quantities of energy that power these objects must come from some source. During the outburst of AO235+164, it was the most powerful object observed in the universe. Emitting energy at the rate of 10^{41} watts, its output was that of about 100 billion suns. Theoretical astrophysicists, who must explain how these incredible amounts of energy are produced, have offered many explanations, ranging from massive black holes (see "Are Black Holes Really There," ASTRONOMY, October 1978) to superdense concentrations of stars triggering frequent supernova explosions.

Whatever the source of energy, one thing is agreed upon by most astronomers: Of all high-energy objects, blazars give the best view of the central energy source, or "the machine" as it is called. Whether the best model is given by the Blandford-Rees "two views" model or by some other process, it is clear that blazars will remain in the forefront of research in extragalactic astronomy for some time to come.

Jack R. Schendel of the University of Pittsburgh is currently completing his Ph.D. dissertation on massive, rapidly rotating stars. His technical background is in relativity theory and theoretical astrophysics, and he has recently completed a study of the dynamics of radiation driven shock waves at the Los Alamos Scientific Laboratory.

ASTRONOMY

IN FOCUS

We are reprinting the following fund raising letter from the L-5 Society, a group actively promoting space colonization, because of its interest to our readers:

Dear Friend / A major emergency has arisen. The United Nations is expected shortly to open for signature the "Agreement Governing Activities of States on the Moon and Other Celestial Bodies." President Carter currently plans to sign it. But this treaty is a disaster for those of us who would go into space.

Among other things, the promise of space is a promise of freedom, of frontiers where opportunities await those willing to try, where social experiments as radical as those which gave birth to our nation can be tried.

It will probably not surprise you that the centralized authority governments of the Earth want none of this. The Moon treaty is a major step in limiting the forms of economic systems permitted in space to a single OPEC-like monopoly. It is also a major step in eliminating civil liberties for those who go into space, as one provision of the treaty allows any government to inspect (i.e., search) any object on or in orbit around any celestial body. No warrant needed!

What can we do? The first step is to try to keep Carter from signing the treaty. Professional lobbying will be needed, but if we are to be successful at this stage, it would be a real bargain, costing perhaps as little as $40,000. This figure has been quoted to us by Leigh Ratiner, the international law expert who coordinated the Moon treaty opposition to date.

Failing here, we must fight ratification of the treaty in the Senate. That gets expensive: $75,000 to kill it in committee, $500,000 if we have to fight it on the floor. Opponents of the Panama Canal Treaty spent millions in their fight.

The consequences of losing are severe. A ratified treaty becomes part of the supreme law of the land. According to space lawyer Art Dula, it would open both private companies and government agencies to suits blocking research on, or investment in, the use of extraterrestrial materials.

The L-5 Society is not alone in these concerns. The American Astronautical Society, *Future Life*, and *OMNI* have already joined forces with us. The National Space Institute and Aerospace Industries Association seem likely to follow.

Please join with me today in this work. Send us your check for $100, $50, or whatever you can afford. With your help, freedom in space will prevail.

H. Keith Henson
Chairman, Moon Treaty
Fundraising Chairman
1620 N. Park
Tucson, AZ 85719

Sir / Saturday, April 26, 1980, has been set aside for Astronomy Day 1980 by many astronomy groups, planetaria, museums, and observatories.

Most Astronomy Day activities include public star parties and exhibits, although lectures, films, demonstrations, telescope making demonstrations, planetarium shows, and guided tours of observatories are also popular. Many parks, schools, and public museums have their scheduled activities manned by local astronomy groups or students.

Astronomy Day provides "hands-on" exposure to astronomy for the general public on a national scale. It has proven to be an effective means of sparking interest and greater participation for large numbers of individuals. The most effective programs seem to be those held at shopping malls or museums where large crowds can be expected if spurred by support from local news media.

If your group is interested in organizing Astronomy Day activities for your area, special information packets are available from the Astronomical League, the Astronomical Association of Northern California, and the Western Amateur Astronomers. In California and Nevada, contact Douglas Berger, 510 Castro Street #J, San Leandro, CA 94577; in other states write Irene Sacks, Morris Museum, P.O. Box 125, Convent Station, NJ 07961.

We hope that your readers will find this information of interest.

Thomas M. Colwell
Seattle, WA

Sir / There is only one word I can think of that describes your coverage of recent space trips — especially those to Jupiter — and that's THRILLING! What an exciting time to be living — astronomically — as well as having all the new discoveries in other fields of art and science, too!

I particularly enjoyed the October Forum — "A Personal Voyage to Jupiter" and "FAR OUT — by Jove!" Having sat glued in front of my TV set for hours during that historic occasion, I can only say "AMEN!" I loved the comments about the press briefings.

Two other departments in your magazine have a special appeal for me (aside from the features covering the recent space events). First is your informative and up-to-date Astro-News — so important in these exciting and fast-moving days. Second is your Astronomy Reviews. I must select my astronomy books very carefully because of limitations of finances and space — they have to compete with all my other science/nature books and collections. Your reviews are invaluable because they apprise me of the quality, level, and contents so I can concentrate on the really new material.

Virginia Johnson
Pleasant Hill, CA

Sir / On Thursday, September 20, 1979, I heard a radio commentator mention a large solar flare had been observed and that the northern lights might be visible on Friday evening. I had not seen a good auroral display for a couple of years, so I planned to view them on Friday. However, a weather forecaster predicted rain on Friday, so I decided to try to view the northern lights on Thursday.

By 10 p.m. I began to notice an unusual "false twilight" covering approximately 40° of the northern horizon. I had never witnessed such a bright glow of the sky in that direction. I was quite sure that something was happening below the horizon. However, it was shortly after midnight when the aurora really began to show. Suddenly, the sky lit up with numerous rays shooting well over 45° above the horizon. The colors of the rays most evident were pale greens, blues, and whites.

This very brilliant display lasted for an hour and a half. During this time countless rays were jumping over the northern sky. I was enthralled with the display and after taking twenty pictures of the aurora, I leaned back and watched a beautiful "light show."

In reflecting on this experience, I am very thrilled at being lucky enough to have heard of this solar flare so I could spend a few hours outside witnessing one of nature's most colorful performances. I only wish the media realized how truly breathtaking an auroral display can be so they would eagerly announce it on the radio and in the newspapers.

Robert A. Veilleux
Manchester, NH

Sir / With reference to the Gazer's Gazette ("Observe a Quasar!") in the December 1979 issue of ASTRONOMY:

There seems to be some disagreement about the position of the quasar 3C 273. The R.A. and Declination given in the article for 3C 273 would not even put this object on the star chart supplied by the AAVSO which accompanies the article. The AAVSO star map does seem to have been (editorially?) altered, however, since the AAVSO usually does not indicate star magnitudes to the tenths position. Perhaps the grid coordinates have also been redrawn.

Whom do I believe, and where should I look?

Gene Gunn
Rocky River, OH

Mr. Gunn / The positions of 3C 273 for epochs 1950 and 1980 are given correctly in the table. The chart is based on the AAVSO chart for 3C 273, which is drawn with epoch 1855 (because the star positions have been taken from the classic German star catalog, **Bonner Durchmusterung**, *of that epoch). The chart should have included a note to that effect.*

AAVSO charts drop the decimal point on stellar magnitudes, but do give accurate values to tenths of a magnitude — for example, 11.2 becomes "112", and 9.8 becomes "98".

behind
the scenes

red telescope goes to moskow

"What a surprise — winning an Astroscan. My first win — thanks." That's how Harry Moskow of Skokie, Illinois began his letter to ASTRONOMY after winning our monthly renewal notice sweepstakes. You'll have your chance to win, too, if when you receive your first ASTRONOMY subscription renewal notice, you send in your renewal right away. You'll get this notice by mail about three months before your subscription is due to expire — prompt payment means you're automatically entered in the contest. And to be completely fair, we've added a new wrinkle: if you renew for two years, your chances of winning are doubled!

Mr. Moskow, our sixth winner, is director of engineering at the Oxford Speaker Company, a firm that designs and manufactures loudspeakers. He told us this story: "My interest in astronomy, until recently, was entirely academic and related only to the space program. However, about a year ago I found a discarded copy of ASTRONOMY onboard a plane, left by the previous passenger. After reading several articles, I found I liked the easy-flowing rhetorical style in which they were presented and written. I sent in my subscription the same day."

A lot of the credit for that "easy-flowing rhetorical style" goes to Katherine King, recently promoted to Managing Editor. Kathy, a former English teacher, has worked at ASTRONOMY since 1975, starting as our editorial secretary and steadily earning more and more responsibility. Kathy insures that every bit of editorial copy in ASTRONOMY is just right, as well as making sure it reaches Art Director Tom Hunt's desk in time for the issue.

Finally, if you've seen the article about the Two Comet Mission, you know that the mission is in danger. VOIR, featured in the January 1979 issue, will be hanging in the balance next year. Galileo to Jupiter has been postponed until 1986. As a citizen concerned about the future of the space program, you owe it to

yourself to let President Carter (1600 Pennsylvania Ave., Washington, DC 20500), your Senator, and your Congressman know that you support a vigorous space program. Do it right away! If thousands of ASTRONOMY readers each send just three letters to their government, it might make a difference. I, for one, don't want to see American exploration of space grind to a halt in the 1980s.

Sincerely,

Richard Berry

Richard Berry

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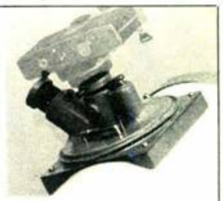

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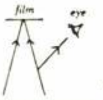

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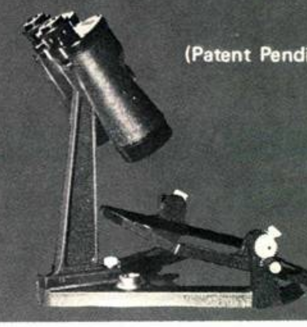

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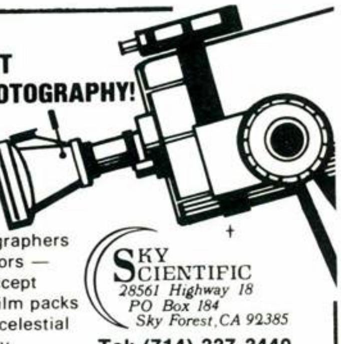

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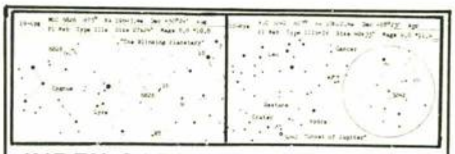

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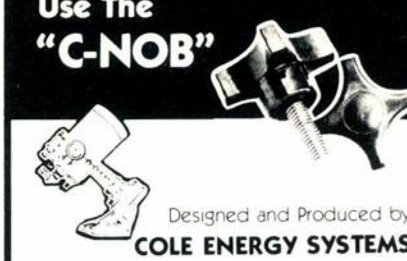

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ANNOUNCEMENT — 26th National American Radio Relay League Convention will be held in Seattle, Washington, July 25-27, 1980. Theme is "World Friendship Through Amateur Radio" and includes world-wide speakers, seminars, manufacturers exhibits. For registration and information write: 1980 AARL National Convention Committee, P.O. Box 68534, Seattle, WA 98168.

ANNOUNCEMENT — The Astronomical Society of Greater Hartford, Connecticut, meets on the 3rd Wednesday of the month at 8 p.m. at the Gengras Planetarium, 950 Trout Brook Dr., West Hartford, CT. Public is invited. For details call (203) 633-1829.

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ANNOUNCEMENT — Pro-space movement must become organized to increase NASA's budget and strengthen our space program. Pro-space groups are urged to write: The Coalition for the Advancement of Universal Space Exploration (CAUSE), Martin Sickler, 1285 Koe St., San Diego, CA 92114.

ANNOUNCEMENT — Western Observatorium Inc. meets monthly, 1st Friday, 8 p.m., Rio Hondo College, S-232, Whittier. Amateurs and professionals welcome. Activities include lectures, public education, observatory building in southern California. Write 13215 E. Penn, Suite 411, Whittier, CA 90602. Phone (213) 698-0468.

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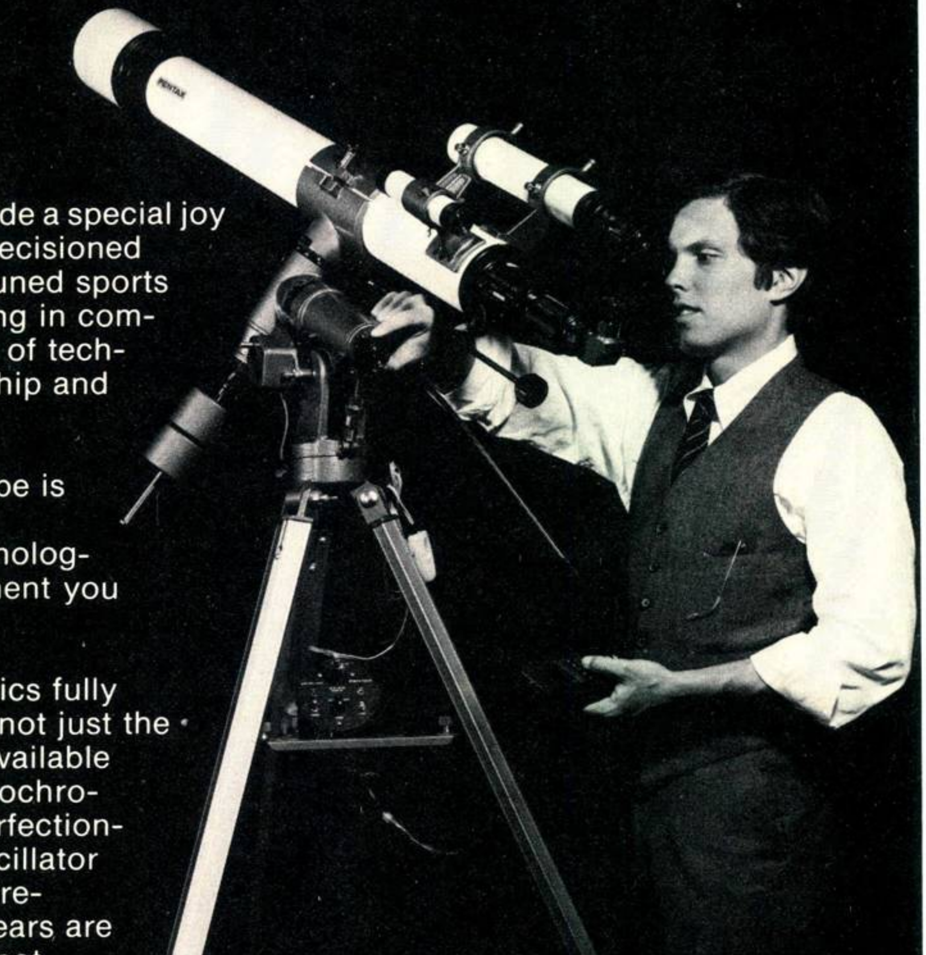

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february: close-up on cancer

by
James Mullaney & Dewey Schwartzenburg

February evenings bring more of the immensely long constellation Hydra rising above the southeastern horizon. Hydra, the water-snake, is one of several snakelike constellations, the others being Draco and Serpens. While Serpens does not rise until the early hours of the morning in February, Draco, a circumpolar constellation, is always visible in the north. At this time of the year, however, Draco is low in the sky, riding just above the northern horizon. At lower latitudes the dragon's head sinks, ostrichlike, below the horizon as though he were trying to hide from his larger brother Hydra.

These serpentine constellations, at least one of which is visible at all times, are related to other constellations by a number of myths in which monster-snakes and dragons figure prominently. They testify to the powerful hold of the dragon symbol upon man's imagination. Of all the imaginary animals that have inhabited the mind of man, the dragon is the most universal and seemingly the most mysterious and powerful. Virtually all cultures, from the Far East to the Medieval West, have fantasized about dragons and their encounters with man and the world.

The characteristics of the serpentine monster have varied from place to place and time to time, but in general a dragon is a giant, snakelike beast, often winged but in any case almost always capable of flight, and in practically all cases a particularly powerful being. Not all dragons, it seems, breathe fire, but all are immensely strong. Wealth is often associated with the dragon, who is also often endowed with a great and cunning intelligence.

The dragon in all his manifold manifestations seems to express a consciousness of the possibilities of being. He is a symbol of nature and an embodiment of its spirit, containing within himself all the potentialities of life. He is stronger than all other creatures, more mobile (with the power of flight), invincibly armored in scales, of surpassing cunning and cleverness, and unlimited by death.

As the pinnacle of nature's potentialities, dragons have been seen in association with every conceivable aspect of nature: mountains, rivers, forests, seas, and the heavens themselves. They constitute the animating principle of these things, the power which holds them in existence. As such, they are also fearful, for their creative power is also a power of destruction. Lightning is the fire of the heavenly dragons, earthquakes the rustling of the earthly snakes. Tsunami (tidal waves) are caused by the heaving of the giant dragons which inhabit the sea, just as the calmer everyday tides result from their breathing.

If dragons have been fearful symbols of creative and destructive power, they have also been subjected to the humiliation of having peculiarly human emotions ascribed to them as well. On this more mundane level, dragons have been seen as the cunning thieves (or sometimes guardians) of gold and jewels, and even human maidens.

In popular myths, the hero often disposes of the dragon in an almost comic way. In one of the most ancient of all Japanese myths, a great eight-headed water dragon busied himself by systematically devouring the daughters of the god of the land. The weeping of the god over his eighth and last daughter, next in line for sacrifice to the monster, attracted the attention of the great semi-divine hero Susa No, the son of the Creator.

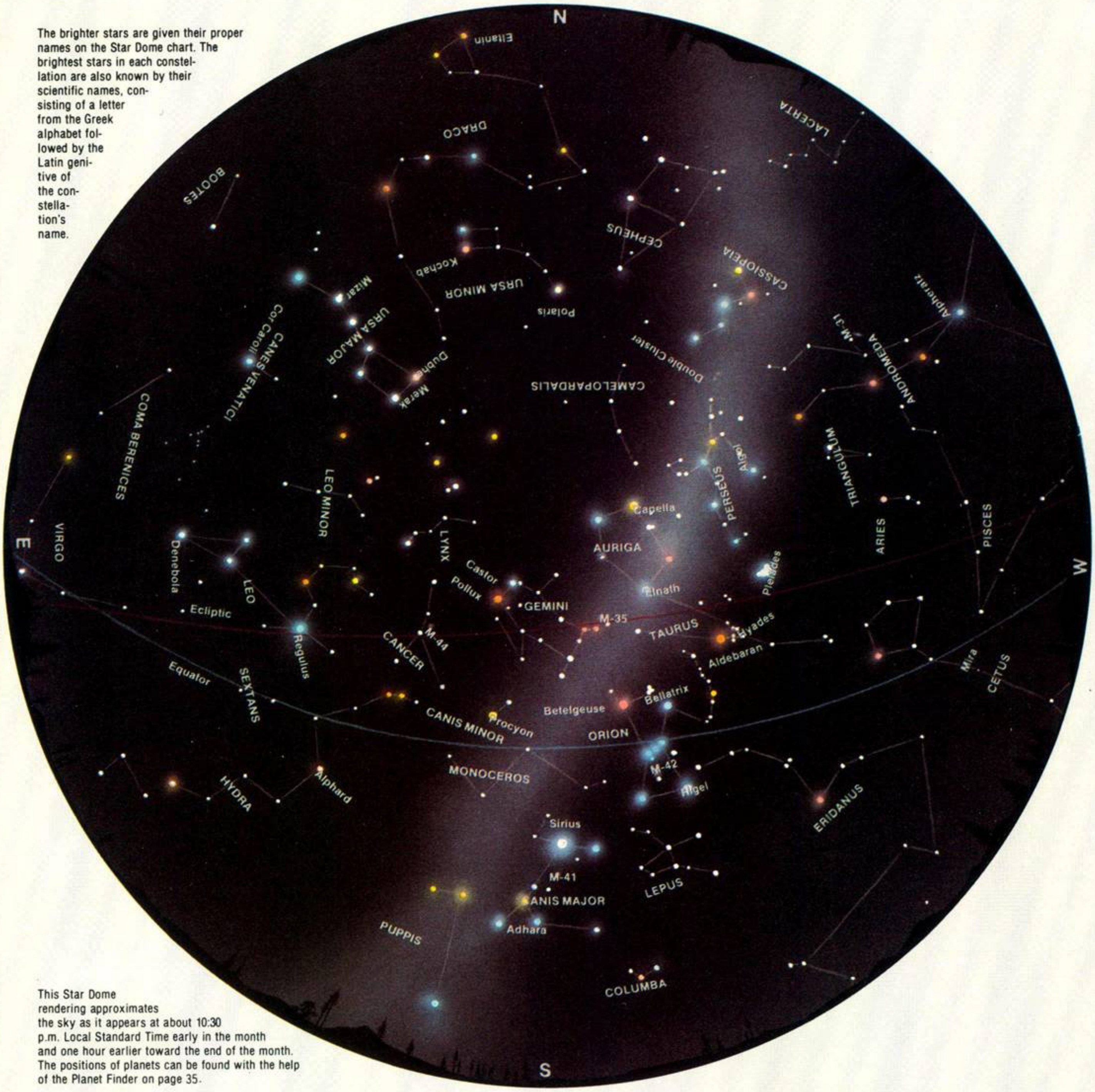
Susa No concocted a clever plot to trap the beast. Having constructed a special house with eight rooms, he placed a giant vat of rice wine in each one. When the dragon arrived for his lunch, Susa No dressed himself as the girl so that the monster would be fooled by his appearance. Poking one of his huge heads into the first of the eight rooms, the dragon saw what looked like an especially appetizing tidbit in the vat of rice wine — the reflection of Susa No "in drag" on the roof above. Wasting no time in polite conversation, the dragon's head quickly gulped down the reflection, in the process also managing to consume an enormous quantity of rather strong wine.

Meanwhile, the other heads had been investigating the other rooms of the house, where they found only large wine-filled vats. But as soon as the first vat of wine had been emptied, Susa No quickly moved to the roof of the second room and positioned himself so that the second head would see his reflection in the wine. Thus suitably enticed, the monster soon quaffed a second round of saki *cum* virgin — or so he thought.

This routine was repeated in all of the eight rooms, with all of the eight heads each having its draught from each of the eight vats. Needless to say, such a succulent surfeit of saki was more than even a dragon could handle, and in no time Susa No had one very drunk dragon on his hands. Of course it wasn't long before the drunk dragon found himself missing eight rather valuable heads, and Susa No went on to marry the surviving princess, become king, and — to a large extent anyway — live happily ever after.

The western hero Hercules had a somewhat more difficult dragon to deal with in the second of his famed twelve labors. In the first place, the Hydra had nine instead of eight heads, although some authorities put the count at a hundred or even ten thousand. The exact number doesn't really matter too much, though, because one of the unfortunate

The brighter stars are given their proper names on the Star Dome chart. The brightest stars in each constellation are also known by their scientific names, consisting of a letter from the Greek alphabet followed by the Latin genitive of the constellation's name.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CANIS MINOR
Procyon
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MONOCEROS
M-42
Rigel
HYDRA
Alphard
ERIDANUS
Sirius
M-41
LEPUS
CANIS MAJOR
Adhara
PUPPIS
COLUMBA
S

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month and one hour earlier toward the end of the month. The positions of planets can be found with the help of the Planet Finder on page 35.

characteristics of this particular dragon was its penchant for replacing any particular head which an aspiring hero might have severed with *two* heads — and that immediately. This ability makes any dragon-beheading project rather frustrating, of course.

Hercules managed to solve the problem of multiplying heads, though, by searing each severed neck with a flaming branch as soon as the offending head had been removed. The only problem remaining was that at least one of this superfluity of heads turned out to be immortal, and even when severed, managed to go right on hissing and sputtering and generally being quite unpleasant. The best Hercules could do with it was to bury it under a rock where, presumably, it has gone right on living ever since.

Cancer, the crab, comes into this story too, for the creature was sent by Hera to cause more trouble for Hercules while he was trying to deal with the dragon. The crab nipped at Hercules' feet as he struggled with the Hydra's ever-multiplying heads, but Hercules, in no mood to be distracted at such a time, quickly dispatched the offending crustacean with a shell-crushing stomp. Nevertheless, Hera rewarded the crab by placing it in the heavens right next to the form of the Hydra, as one of the twelve signs of the zodiac.

Another myth which is associated with the constellation Hydra involves the hero Jason and his quest for the Golden Fleece. The King of Colchis, Aetes, had hidden the fleece in a cave and set a particularly large, loathsome, and unfriendly dragon to guard it. This dragon, reputed to have a thousand coils and to have been larger than Jason's ship the Argo, also happened to be both sleepless and immortal.

In this case the hero had more of a dragon than he could deal with. Presumably Jason would never have been able to handle it on his own, but fortunately he had the assistance of the witch Medea, the daughter of the king. Medea had fallen in love with

Jason and sought to assist him in his quest. Therefore Jason was able to relax and take it easy while Medea dealt with the beast by the typically devious means of witchcraft. Chanting suitable incantations and spells, Medea, who obviously didn't have the common fear of snakes, lulled the dragon until she could walk right up to it. That was the monster's undoing, for she was then able to sprinkle a sleeping potion into its never-sleeping eyes. Jason snatched up the Golden Fleece while the loathsome creature slumbered like a baby, quietly hissing in its sleep. After the escape of Jason and Medea, the monster was placed in the sky as the constellation Hydra.

Jason had another adventure involving a dragon, or rather the teeth of a dragon, but we'll save that for next month. And as for those who say there are no dragons and that they are only a figment of the imagination, well, they have only to look up into the night sky to see the mighty and fearsome beasts coiling and hissing still.

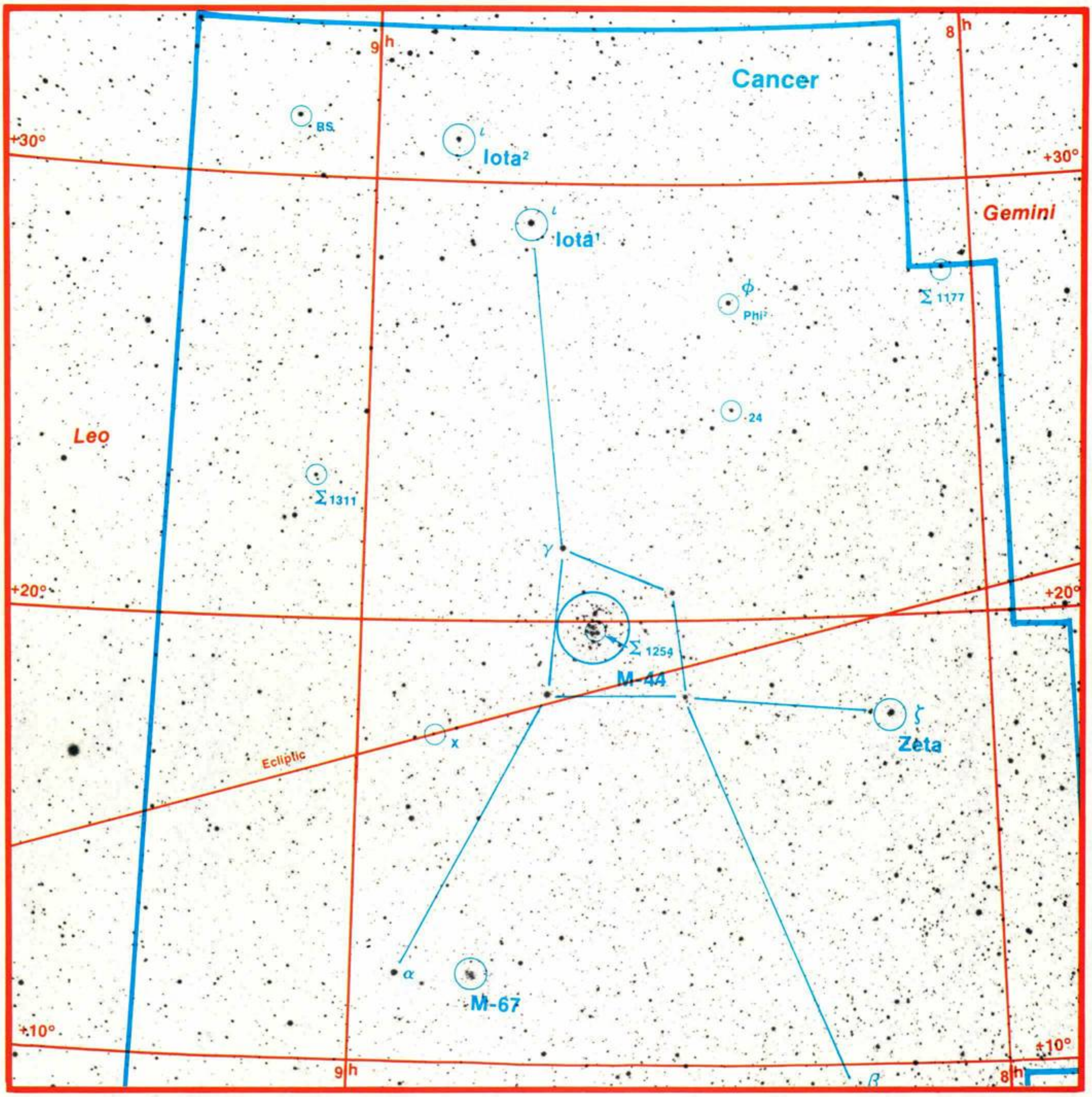
close-up

Cancer

Ranking 31st in size among the 88 recognized constellations, the obscure zodiacal figure of Cancer lies between Leo and Gemini in the late-winter evening sky. The body of the celestial crab is dimly outlined by an irregular square formed by the stars Delta, Eta, Theta, and Gamma while its claws are marked by a number of surrounding ones such as Alpha, Beta, Iota, Zeta, and Xi. On a dark transparent night, little imagination is required to visualize a huge crab stalking its neighbors across the sky.

Iota^1 (ι^1) Cancri

We begin our telescopic survey of Cancer's deep-sky wonders with a look at a beautiful "copy" of the famed double star Albireo (Beta [β] Cygni). This is 4th magnitude Iota^1 (ι^1) Cancri, easily found by extending a line from Delta (δ) through Gamma (γ) 7° northward. In looking for it, be sure not to confuse Iota^1 with Iota^2, 2° to



the northeast — an interesting triple system as indicated in our table of selected objects.

Discovered by Sir William Herschel in 1782, this pair can be resolved in a good finder or mounted binoculars and is a stunning sight in even the smallest of telescopes. Here we find a 4.2 magnitude yellowish-orange primary and a 6.6 magnitude blue companion 31 seconds of arc apart in position angle 307° (northwest-southeast on the sky). A 3 or 4-inch telescope at 45 power gives a superb view of this object. Larger apertures brighten the view, but higher magnifications tend to separate the components unduly — somewhat muting the pleasing magnitude and color contrast effect present here.

Among the tints reported by various observers for Iota¹ Cancri are pale orange and clear blue (Smyth), crocus and violet (Barns), and yellow and blue (Olcott). Webb simply remarked "beautiful contrast" and pointed out that another much fainter double (called Struve 1266) lies in the field to the southwest. Its components are 8th and 9th magnitude; their separation is 23 seconds. Brown saw Iota's tints as pale yellow and light blue, remarking "easy in any telescope."

This lovely duo appears on many lists of showpieces including that published in the 1890s by Colas of the finest colored doubles. It is a "Grade 2" object (or runner-up) in Pickering's prestigious 1917 roster of the sky's 60 best objects. How do you rate its visual appeal in your telescope?

The spectral types of Iota¹'s primary and secondary are G8 and A3 respectively, agreeing well with most color impressions at the eyepiece. The components are relatively fixed in position angle and separation, forming a common proper motion pair drifting through space together. If you've ever wished you had Albireo in the winter sky to show visitors, here's the ideal substitute for it.

Zeta (ζ) Cancri

Our next selection is a difficult but fascinating triple star, described by Robert Burnham, Jr. as "one of the most remarkable of all known multiple star systems." This is 5th magnitude Zeta (ζ) Cancri, readily located by extending a line to the southeast from Castor through Pollux (in neighboring Gemini) roughly three times their separation.

Zeta consists of a very close pair of 5.6 and 5.9 magnitude yellow suns, presently 0.8 second apart in position angle 286°. There is also a 6.0 magnitude yellow member 5.9 seconds distant at 81°. (This last object seems fainter to many observers than the value usually given, and the noted double star measurer Charles Worley rates it as low as 7.3 magnitude.) The close pair forms a visual binary with an orbital period of just 60 years, while the outer star circles them in a period estimated at 1150 years. The separation between the pair of suns was widest at 1.2 seconds in 1960 and is now closing to a minimum gap of about 0.5 second expected about 1990. Thus a telescope-power combination that just splits this tight duo now should show their images merging over the next few years as the separation continues to decrease — striking visual evidence of stellar orbital motion.

A 3-inch refractor at about 90 power divides Zeta into a double, and a 4-inch glass shows the third star at 200 magnification in good seeing (image steadiness). In 6-inch and larger instruments, this object is an attractive sight at medium to high powers on a steady night. All three stars appear golden yellow in hue, their spectral types being F8, G0 and G2, respectively.

Brown described Zeta as a "typical 'big telescope' triple, meaning it has an easy spread of 5 seconds and another separation not so easy at 1 second." Noting that Cancer "offers many allurements" for the telescopist, Barns listed it as a test object in his 10-inch reflector. So did Webb in his account, which reads in part: "Excellent test, close pair, well-separated with an 8-inch speculum (reflector) at 300 (power), when at 0.5 second separation."

Muirden saw Zeta Cancri as follows: "Three stars, all yellow. A splendid sight." While absent from many lists due to its tightly bound nature in small instruments, this trio certainly deserves wider attention than it has been accorded in the past. Pickering obviously thought it a worthy object, for he placed it in his compilation under "finest multiple stars." Do you consider it a showpiece or a disappointment in your telescope?

In addition to the visual members of the Zeta Cancri system, there is an unseen companion orbiting the wide star with a period of 18 years. And extending our scrutiny into the spectroscopic realm, there is yet another member suspected here. Thus, were we living on a planet orbiting Zeta, we might find as many as *five* suns shining in our alien sky. This remarkably complex system lies about 70 light-years, or more then 400 trillion miles, from us.

M-44

To the unaided eye, the most interesting visual feature of this month's dim region is the big loose open cluster of stars, M-44. Lying within the boxlike body of the crab, it looks very much like a large nebula on a moonless night and has even been mistaken for a new comet on occasion. Known since Roman times as Praesepe (Latin for "the manger"), it is more commonly called the Beehive Cluster — perhaps due to its resemblance to a cosmic cloud of bees swarming in the night.

Glowing softly with an integrated light equal to a 3.4 magnitude star, M-44 spans nearly three full moon diameters of the sky (over 80 minutes of arc in apparent size). A fine sight in binoculars, finders, and richest field telescopes, it tends to be disappointing in typical telescopic views because the observer is unable to encompass the entire cluster at once. The central portion of the Beehive is about 10 light-years across, with its outer stragglers extending more than three times that figure through space, and the center of the clan lies some 525 light-years away. This makes it one of the nearest members of its class, partly accounting for its great apparent size in our sky.

The resolution of M-44 was one of the first conquests of Galileo's newly constructed "optick tube" in 1610. He counted some three dozen stars here, and we are told that the sight of these glittering gems filled him with delight and utter amazement. As with clusters in general, the number of member stars visible depends on our limiting magnitude. In the case of the Beehive, there are at least 80 physical members down to about 10th magnitude and several hundred to 14th magnitude. Counting the individual stars in a rich open cluster can be a frustrating experience, but in a big loose one like this, it can be real fun. How many stars can you see here on a dark night?

Considered more a binocular than a telescopic object, M-44 is omitted from many lists of celestial attractions. Yet it does offer much of interest to the telescopic observer. Webb remarked "too large for usual fields but full of fine combinations. Two triangles will be noted." And Barns in his 10-inch reflector found "many doubles, triples, multiples, stars of varied hues" here. One of these objects is the fine multiple star Struve 1254 listed in our table.

Burnham called M-44 "one of the largest, nearest, and brightest of the galactic star clusters," which it certainly is. Pickering included it in his list under finest coarse clusters, calling it "a well-known naked-eye cluster." Brown logged it as "a popular wide-field open cluster" and warned "you may have to use your finder to catch all of it." Holyoke's account reads in part: "Binoculars of very low power give the best views. Remarkable for the number of little pairs and triangles of stars." And in like manner, Muirden found the Beehive "a coarse cluster of bright stars, best seen in the finder since it is too extensive for ordinary

Selected Objects — Cancer

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.
Σ 1177	★^{2}	6.5,7.5	3″	08^h03^m	+27°40′
*Zeta	★^{3}	5.6,5.9,6.0	1″,6″	08^h09^m	+17°48′
Phi^2	★^{2}	6.3,6.3	5″	08^h24^m	+27°06′
24	★^{2}	7.1,7.6	6″	08^h24^m	+24°42′
Σ 1245	★^{2}	6.0,7.2	10″	08^h33^m	+06°48′
*M-44	○	3.4	80′	08^h38^m	+19°52′
Σ 1254	★^{4}	6,9,8,9	20″,63″83″	08^h38^m	+19°51′
*Iota^1	★^{2}	4.2,6.6	31″	08^h44^m	+28°57′
*M-67	○	7.0	15′	08^h48^m	+12°00′
*Iota^2 (=57)	★^{3}	6.3,6.5,9.2	1.5″,56″	08^h51^m	+30°46′
X	m★	5.9-7.3	170^d	08^h53^m	+17°25′
Σ 1311	★^{2}	6.7,7.2	8″	09^h05^m	+23°11′
RS	m★	5.5-7.0	120^d	09^h08^m	+31°10′

*Detailed in Close-Up

- *Star*
- *Bright Star*
- *Double Star*
- *Triple Star*

m★ *Regular Variable*
n★ *Irregular Variable*
H★ *Eclipsing Variable*

○ *Open Cluster*
● *Globular Cluster*
■ *Planetary Nebula*
Bright Diffuse Nebula

§0 *Elliptical Galaxy*
§S *Spiral Galaxy*
§/ *Barred Spiral Galaxy*
§# *Peculiar/Irregular Galaxy*

telescopic fields."

Strangely, the *NGC* doesn't describe M-44, listing only "Praesepe Cancri" and attributing its discovery to Hipparchus — though its presence was certainly known throughout antiquity. Mallas gave its integrated light as 4.5 magnitude and notes it as a "fuzzy glow 1° across" as seen with the unaided eye. In his small refractor, he found: "While...too sprawling a group to give a good view in the 4-inch even at 25 power, this instrument does show well the colors of the brighter stars." The colors themselves are mentioned in Norton's description, which reads: "A large scattered cluster almost resolved by the naked eye; contains some orange stars." Indeed, while most of its brighter units are blue-white A-type suns, there are a number of golden-orange K-type ones present as well.

With the advent of many new types of wide-angle, low-power (long focal length) oculars on today's market for the observer, M-44's telescopic appeal should be on the increase, since more of its glittering stellar jewels can be fitted into the wide field of view. If you're one of those who has "written off" the Beehive as unworthy of showpiece status, perhaps you should take another look at it the next clear night with that new eyepiece you've been showing off.

Before taking leave of this ghostly celestial clan, another fascinating visual feature about it should be noted. In ancient times, visibility of the Beehive Cluster was regarded as a sort of visual "barometer" or weather forecaster. Among other early sky watchers, Aratus and Theophrastas noted in the year 300 B.C. that this object's invisibility in an otherwise clear sky signaled the approach of a storm. Lying near the magnitude threshold of the average unaided human eye, even the slightest obscuration by high altitude cirrus ice crystals is enough to render it invisible. It's these very same crystals that produce the prismatic halos sometimes seen around the Sun and Moon — another omen of approaching weather fronts. M-44's usefulness as a weather indicator is still effective today, so why not try it yourself on the fitful nights of late winter and early spring?

M-67

Lying just 9° south of the Beehive is another prominent open star cluster — M-67. Look for it in your finder or a low power eyepiece, slightly less then 2° due west of 4th magnitude Alpha (α) Cancri. Slow sweeping is sure to show it on a dark night, appearing as a nebulous patch in finders and binoculars.

M-67 has an integrated light variously given as between 6th and 7th magnitude. Its apparent angular size is also subject to opinion — 15 minutes is generally given but values twice as great have been reported by some observers. About 65 suns are packed into this area, giving the cluster a fairly concentrated appearance. Herschel counted over 200 stars here in his large metal-mirrored reflectors and the cluster membership may exceed 500 down to the 16th magnitude.

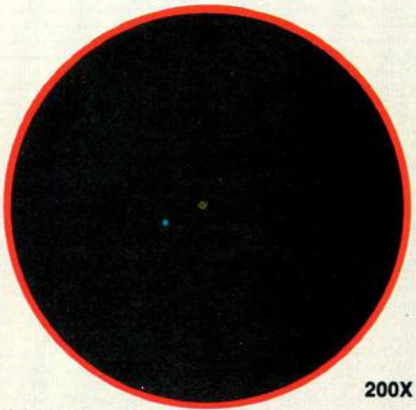
This rich swarm of rather faint stars is easily broken into individual pinpoints in a 3 or 4-inch telescope at 45 power, and is a fine sight in 6-inch and larger instruments at magnifications of 50 to 100. Mallas found this object "an easy cluster to resolve. In the 4-inch (refractor), the star hues of M-67 are predominantly rust, orange, gold and yellow."

Interestingly, Webb had little to say about this fine object, tersely noting: "Cluster. Visible in finder." Barns went further, calling M-67 "vivid, rich type of its exalted class." And Muirden found it "a splendid scattered cluster of bright and faint stars." Brown pointed out that this object is small compared to the Beehive, and Olcott that it "is composed of stars of magnitudes 9 to 12.5 surrounded by brighter stars in the form of a semicircle. The cluster as a whole resembles a nebula in a small instrument."

The semicircle mentioned by Olcott is quite obvious in small apertures, becoming less apparent as telescope size increases due to the "filling in" effect of the fainter stars. Other shapes may be seen, depending on telescope size, magnification — and imagination. Norton saw M-67 as "a roughly circular open cluster of faint stars" and called it a "low power object." (His value for the apparent size was 27 minutes of arc.)

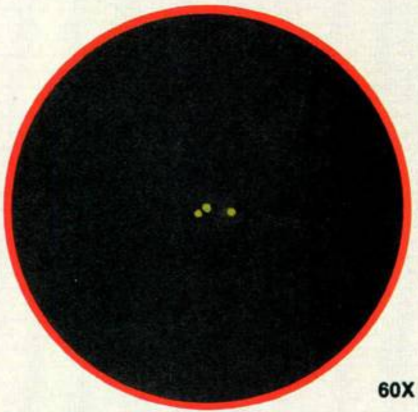
The *NGC* description of M-67 reads: "Remarkable. Cluster, very bright, very large, extremely rich, little compressed, stars from 10th to 15th magnitude." Holyoke logged it as "a galactic cluster which is easy in any telescope and resolved by low powers." Burnham called this object "one of the most ancient known galactic clusters" — which it indeed is, for it has been dated as about 10 billion years old. Only NGC-188 in Cepheus is known to be older among all the open star clusters.

Top: Iota^1 Cancri, with its delightful color contrast, can serve as a winter subsitute for Albireo. Middle: Zeta Cancri may consist of as many as five stars, but only three are visible. Drawings by James Mullaney. Bottom: M-44, the Beehive Cluster, should be viewed at low magnifications. Photo by T.L. Dessert.



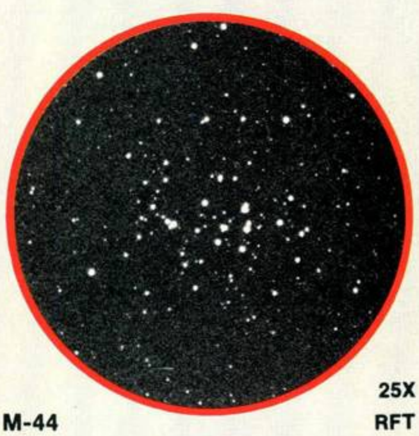
200X

Iota^1 Cancri **6-inch reflector**



60X

Zeta Cancri **3-inch reflector**



25X

M-44 **RFT**

This remote clan lies some 2500 light-years from us — five times as distant as the Beehive Cluster. (This accounts in part for the fact that the latter object is about five times as large in apparent size in our sky as the former.) As we jump from relatively nearby wonders like M-44 to distant ones like M-67, the volume of space we are surveying — our sphere of inquiry — increases enormously (25 times in this case). This brings to mind a remarkable insight expressed by an unknown writer, to the effect that "the larger the sphere of our knowledge, the greater the contact of its surface with the infinity of our ignorance." Truly, we should approach the eyepiece with an open mind and a humble heart.

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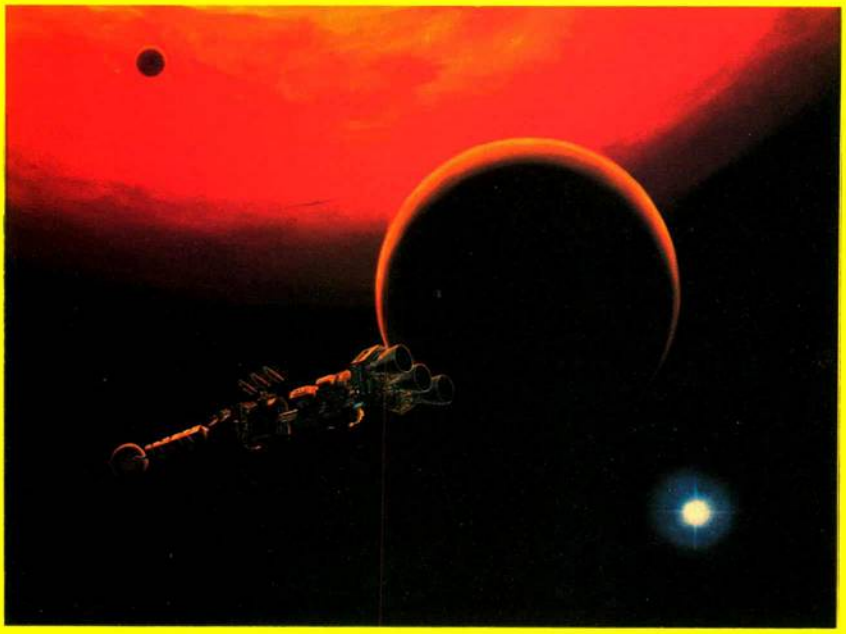

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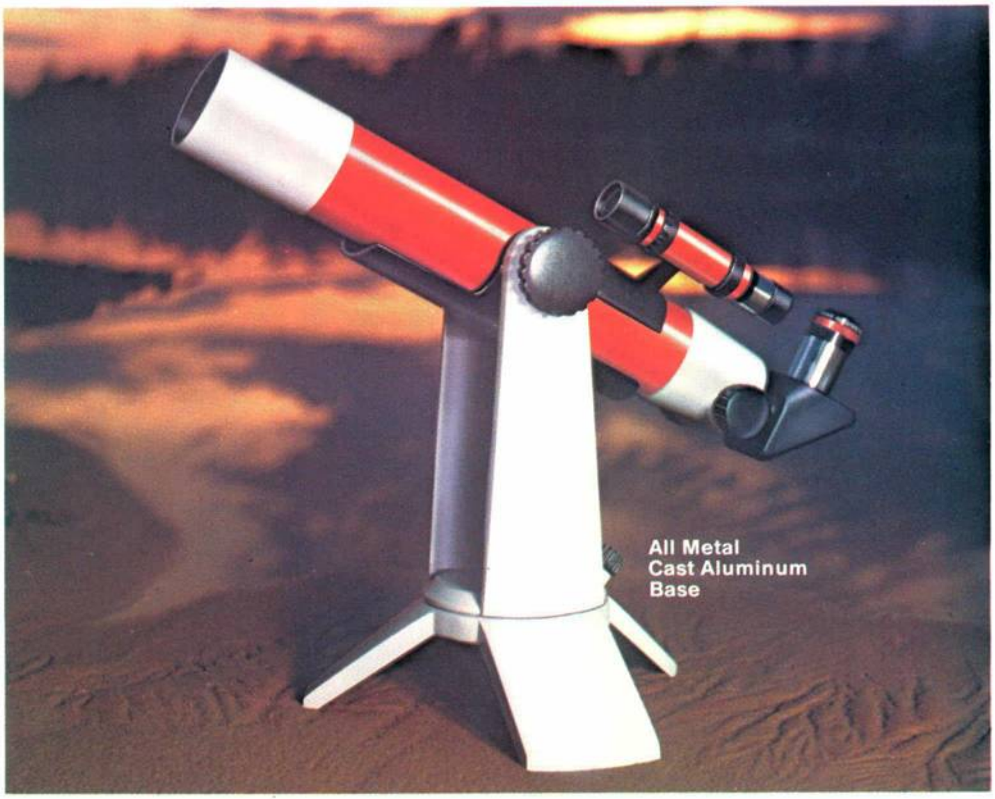

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